FIRE HAZARDS IN TEXTILE MILLS,

MILL ARCHITECTURE,

AND

MEANS FOR EXTINGUISHING FIRE.

[THREE LECTURES DELIVERED BEFORE THE FRANKLIN INSTITUTE. REVISED FOR PUBLICATION IN THE JOURNAL OF THE FRANKLIN INSTITUTE, AND PRINTED BY PERMISSION OF THE COMMITTEE ON PUBLICATION.]

BY

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Member of the Franklin Institute, American Association for the Advancement of Science, Philadelphia Engineers' Club, German Chemical Society of Berlin, Associate of the American Institute of Mining Engineers, Etc., Etc.

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PREFACE.

This little book contains the stenographic notes of three lectures recently delivered before the Franklin Institute. It was not the intention of the author to print them, as he wished to use them for the foundation of a larger illustrated work. Requests to publish them have, however, been so numerous, not only from underwriters and textile manufacturers, but the press in general, that the manuscript was reluctantly allowed to go to the printer.

The writer hopes that he has, to a limited extent, made up for what is wanting in rotundity of diction, by a concise statement of *facts* which represents the labor, hard study and original research of years.

Philadelphia, March 1, 1885.

FIRE HAZARDS IN TEXTILE MILLS.*

When we consider that in the year 1883 about one hundred million dollars' worth of property was destroyed by fire throughout the United States, and if losses continue at the present rate they will this year amount to one hundred and twenty-eight million dollars, we must admit that the study of fires and their causes is of intense interest and of the greatest practical value. For the sums just quoted are so great that the mind cannot conceive them; it is only by comparison that we can arrive at an approximate idea. Let us suppose that a clerk was counting off single dollar notes for the payment of these losses, and that he could count at the rapid rate of 100 in a minute; it would take him 2·43 years to complete his task, without a moment of sleep or rest. Or suppose I placed one dollar notes representing the amount of this annual fire waste in line lengthwise, edge to edge; it would form a line of greenbacks 7,893,333·3 feet long; or, to express it in miles, a strip 1,494·9 miles in length.

One of our technical papers, in moralizing on the annual fire loss over a year ago, truly said:

> "All of the former huge amount of property has literally been blotted out of existence. Whether the losses were borne by the insurance companies or by individuals, the result is the complete extermination of just so much wealth which was created by human effort and ingenuity. The world is poorer by that amount than it would have been could these fires have been avoided.
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> "A person who considers these facts and figures thoughtfully must be impressed with the conviction that the existing means of preventing and extinguishing fires are either very inadequate or very greatly neglected.
>
> "The whole matter will have to receive more consideration in the future than has hitherto been given to it. Civilized society, which leans so much upon human industry, cannot afford to permit vast quantities of the fruits of industry to be blotted out every year, when preventives are within reach."

As is the case in other investigations, it is most difficult to discover the origins—used here in its true sense, that is, causes—of fires. Before preventive measures against enemies of mankind can intelli-

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* A lecture delivered before the Franklin Institute, Dec. 12, 1884.

gently be undertaken, be they epidemics or dangers of the elements, we must first know the causes which underlie the evil we wish to overcome. But the writer and observer on this subject labors under difficulties which the student of no other subject encounters to a like degree. The student of a new disease may note the symptoms of a great number of cases which he can diligently himself examine; we, on the other hand, receive our accounts from persons who observed what we most wish to know, while excited and frightened to a craze, and but seldom do cases occur where not all traces of the origin have been destroyed, while it is exceedingly difficult to obtain information from employés, especially from watchmen, which would reflect badly on their judgment or honesty in performing their duty.

In order to lessen the number of fires, not so much better means for extinguishing, but methods of preventing them, are required; and fires can only be prevented by a proper understanding of fire hazards by all classes. While means for extinguishing fires are daily approaching perfection, fire hazards are daily, through new inventions necessitating the employment of dangerous substances and processes, increased, and it is to the discovery of the hazards of every class of risks, and the invention of preventive means, to which the student of this subject must chiefly turn his attention. It is to the study of the fire hazards of a large class—textile mills—to which we turn our attention to-night.

One of the most trustworthy and complete tables, on the origins of fires in textile mills, is that kept by the Boston Manufacturers' Mutual Fire Insurance Company since October 1, 1850, which was furnished me complete up to January 1, 1884, through the kindness of Mr. C. J. Woodbury, their inspector. This table includes only establishments insured by that company, of the best types of this class. It gives the causes and numbers of fires resulting from them as follows:

Causes.	Number of Fires.
Foreign substances in pickers	165
Friction	187
Spontaneous combustion through oils	115
Matches	52
Lighting apparatus	36
Sparks and defective chimneys	33
Incendiary	20
Spontaneous combustion of dyed cloth or yarn	26
Broken lanterns and lamps	17
Lightning	13

Causes.	Number of Fires.
Fireworks	7
Stoves	4
Pipes and cigars	4
Window glass acting as lens, concentrating the rays of the sun	3
Spontaneous combustion of bituminous coal	3
Electricity from belts	3
Electric light	25
Water inducing rapid oxidation of iron turnings, which set fire to the saw dust mixed with it	2
(One of these was caused by a freshet.)	
Hot irons	2
Cutting iron hoops on cotton bales with axes, sparks setting the cotton on fire	7
Heat from furnaces	5
Wood in contact with boiler setting	1
Result of boiler explosion	1

One was caused by a man accidentally dropping an open penknife on a small bunch of cotton card waste, which burst into flames. After the fire was extinguished, a quartz pebble about one-eighth of an inch in diameter was found on the floor; the steel blade, hitting this pebble, struck the spark which ignited the cotton.

Causes.	Number of Fires.
Matches	12
Gas	7
Steam pipes	5
Mice	1
Hot flues	1
Sparks from emory wheel	1
Petroleum	1
Gasoline vapors	2
Breaking of shaft	1

Let us now turn from statistics to a closer inspection of the hazards, beginning with the raw stock in its process through the mill.

RAW STOCK.

It may be stated, as an almost infallible rule, and I think the experience of underwriters will bear me out, that, under like other conditions, the fire hazard increases indirectly as the quality of raw stock, and therefore also indirectly with the quality of the manufactured goods; that is, the poorer the grade of raw stock, the greater the fire hazard. It is absolutely necessary for a mill inspector to be conversant with the different kinds of raw stock, and he should be able to

make microscopic and chemical tests of the same, in order to determine the exact proportions of mixed stocks for himself, as the statements of the assured may be, and frequently are, incorrect. We will, further on, make microscopic tests, on a large scale, by examining the different kinds of stock, as thrown on the screen by the projecting microscope.

In our part of the country the so-called "mixed" mills are found to a great extent, and these, on account of the greater fire hazard inherent to them, are of special interest to us to-night. In its widest meaning, a "mixed mill" is one in which cotton and wool is spun (by which I include the previous processes of picking). The amount of cotton adulteration in the so-called woolen goods depends on the demands of the market for which the manufacturer is working; therefore the proportions of raw stocks in many "mixed mills" are constantly changing from nearly all wool to nearly all cotton. By wool is meant the animal fibre of that name in any condition, and includes wool, shoddy, extract, waste, etc.

Cotton, as a rule, comes to the mill in a pure state; but, as in wool, there are different grades to be taken into account, not only from their commercial value, but as to their fire hazard in being worked. The most objectionable grade is "damaged cotton," which has undergone partial destruction by fire, and which (in order to conceal the marks of charring) has been dyed with a dark color. Such cotton when run over the cards will create a great amount of fly, and is, therefore, as we shall presently see, much more dangerous than better grades. Dirty cotton has often been the cause of picker fires, and I am informed that bales are sometimes fraudulently loaded with sand and gravel to increase their weight.

As picker fires are generally due to stones, pieces of iron, etc., which, in coming in contact with the whipper, strike sparks, the value of clean carefully inspected cotton, from the fire point of view is self-evident, and also the absolute necessity of better methods and greater care of Southern cotton growers in ginning, baling and transporting it. This desideratum, which could not be instilled into the planters by way of the head and heart, has gradually entered them by way of the purse, as they have found that it is commercially more advantageous to place their stock in the market in a clean condition, and they will, no doubt, very soon deliver it to their customers more free from hazardous foreign particles.

Cotton carding waste is sometimes used in low grade mixed mills,

and as it is very short fibred, being carded out in the white cotton mill, creates much fly and dirt in working it; and mills using it are very dirty and hazardous. Reginned cotton is another low grade hazardous stock.

Wool is a much safer stock than cotton; pure woolen mills are not frequently destroyed by causes directly or indirectly resulting from the stock; and pure worsted mills are among our best risks. It is through the adulteration of the wool that fire hazards are created, and in a direct proportion with the amount of adulteration.

Care should be exercised in wool-sorting rooms, as fires have been caused by the ignition of tar-marked fleeces laid on steam heating pipes to soften the tar used to mark the sheep. Mr. C. J. Woodbury suggests the following safe and efficient manner of softening the tar:

"A box about eight feet long, two feet wide and six inches deep, is provided with a bottom made of wire gauze of about one-half inch mesh. Under this box is a piece of iron pipe, with perforations upon the upper side, and connected with the steam supply. When this box is filled with fleeces, and the numerous jets of steam blown through them, they are softened much more rapidly than by warming in the usual manner around steam pipes or stoves."

Wool shoddy is a short fibred wool manufactured from rags. The picking of shoddy is very hazardous, and it is generally manufactured in extra mills (shoddy mills), and the stock or yarn sold to others. Where shoddy is made in a mixed mill it greatly increases the hazard, and the greatest care must be taken in the location and construction of the picker room. When used in large quantities in mixed mills it becomes a source of danger from the amount of dirt and fly made in carding. In picking the rags at the shoddy mill, much oil is frequently used on the stock. The kind of oil is of great importance, for if animal oils are used spontaneous combustion of the stock may ensue on being piled in quantity, and if some of the so-called wool oils be used, which are mixtures of animal oil and petroleum, the petroleum vapors arising from it during the process of manufacture may become dangerous. Yarns manufactured from shoddy picked with wool oil sometimes contain enough oil, even when dyed, to become dangerous on exposure to a high temperature in the dry house. The reason for this is that mineral oil will not readily saponify. An emulsion of lard oil and water with a little ammonia is the safest

substance to use on wool. Olive oil, which is frequently adulterated with cotton seed oil, should not be used.

Wool Extract is a shoddy manufactured from rags of a mixed stock, the cotton contained in them having been dissolved by dilute sulphuric acid. It has the objectionable features of shoddy.

Worsted waste, when clean from the drawing frames, is a very good stock, as it has been combed, and when not oily is cleaner and safer than raw wool. The so-called woolen noils, which is the soft waste taken from the wool on the combs, is also a good stock but not as good as pure wool.

Silk noils is the waste from the combs obtained in manufacturing spun silk yarns, is but seldom used, and is not specially hazardous.

In the lowest grades of mixed mills, where a cheap carpet yarn is made, hair, jute, flax, hemp, etc., are sometimes used in mixing. These stocks materially increase the hazard of the mill.

As before stated it is not only important for the insurance inspector and adjuster to distinguish a good from a poor grade of wool, but he should also be able to detect any cotton in woolen goods. This may, by practice, generally be detected at sight, or by the rough test of ignition. Animal fibres when singed give off a smell of burnt feathers, and when ignited in the flame of a candle are almost immediately extinguished, a carbonaceous residue being left; cotton and linen fibres continue to burn, do not give off the smell of burnt feathers, and do not leave a carbonaceous mass when extinguished. Where a little potash may be procured, the best and most reliable test is to place a piece of the goods in a solution of caustic potash; the wool being dissolved, the cotton remaining intact.

Another easily applicable test is that of nitric acid. On boiling tissues in this acid, silk will assume a light yellow, wool a dark yellow color, while flax, cotton and hemp will remain white. If the proportions of the different components are sought, a small piece of the goods is taken, carefully washed, to free it of all grease, and dried, this is then carefully weighed and boiled with caustic soda until the animal fibres are completely dissolved. The lye solution is then run through a filter, while the fibres remaining on the filter are thoroughly washed with water. The loss in weight of the fibres when dried will then give the amount of animal matter.

The best qualitative test is an examination with a good microscope. Under the microscope, as we will presently notice on the screen, cotton

has a flowing, twisted, band-like appearance; linen fibres appear as slender cylindrical reeds; wool has a thick circular stalk covered with scales; silk is slender, smooth, and shines brilliantly.

We cannot too well impress that the shapes and lengths of the raw stock are of the utmost importanee in "Fire Technology," and that the causes of a great number of fires in "mixed mills" may be directly traced to the nature (physical and chemical character) of the raw stock used.

Raw wool—although it does not burn readily—is a more unprofitable stock to insure than is generally supposed. There is but a poor salvage on wool. The keratin, the principal part of wool, when wet, ferments and decays, the wool thus becoming worthless. Although a stock of wool may not have been damaged by fire, it may still be a total loss, as, by the water poured upon it, fermentation has set in. If speedily taken care of and dried, wool may be cured, although it seldom regains its original quality.

Let us now turn to the hazards of *Dyeing and Drying.*

The process may be generally divided into: first, the cleaning of yarn, warp, or raw stock; secondly, the dyeing proper; and thirdly, drying. The first operation consists in boiling and scouring the material; this is performed in vats, the scouring being accomplished either by hand or automatically by scouring machines. This operation carries no special danger from fire with it, except where *oily* material is scoured, and then allowed to lie in heaps. When this is the case, we have one of the most favorable circumstances for spontaneous combustion.

The custom of some dyers of adding oil to the stock in the dye-tubs to soften it is a bad one. If properly dried, the oil is superfluous; if dried too hot, the presence of the oil in the stock materially increases the hazard of fire, from ignition of the damp, oily stock, subjected to the heat of the drying chest.

The process of dyeing creates no danger from fire; a hazard lies in the ehemicals stored for the process. We here find unslaked lime (which, on getting damp, has caused fires); sulphuric acid; piles of logwood in the process of "curing," damp and liable to ignite spontaneously, etc. Although we have never heard of a fire caused by the spontaneous combustion of logwood, yet from what such eminent chemical technologists as Muspratt and Stohmann tell us of the nature of the proeess of "curing" logwood, it seems quite probable that fires may originate through its agency. Chlorate of potassium is also sometimes stored, the hazards of which I will speak later.

The material is, after dyeing, sometimes sized, but whether sized or unsized, dried; and it is here that fires in dye works chiefly occur. The danger of a dry house depends greatly on the material dried; for piece goods, warps or yarns the danger is not so great as in the case of raw stock, and especially raw cotton. In the hot summer months, yarns and even sometimes raw stocks are dried on "drying flats;" but, as a rule, they are dried in rooms heated by steam, furnaces, or by the natural heat of the boilers below. The steam pipes are arranged to run either along the floor, the wall, or, which I am sorry to say is seldom the case, along the main ceiling. The last arrangement is preferable, as in that case it will be impossible for the material to drop on the pipes. In this method of drying, the only requirements are that steam pipes rest on iron, as live steam pipes will ignite wood, and that the steam pipes are kept clean. The antiquated method of drying by furnaces is very objectionable, and has, in our country, been almost entirely superseded by the much safer process of steam drying. The last method, which is frequently used where drying rooms are situated over the boiler room, is the most economical process; and, when properly constructed, so that no yarn dust or fibres may fall within dangerous proximity of the boilers or boiler fire, has no special hazard connected with it. Special care should in this case be taken to have the boilers well enclosed by brickwork, and where this is not the case, a thick layer of sand should be spread on top of them, thus protecting them against falling particles.

The hazard of a yarn dry house varies with the nature of the yarns dried. It is safer to dry woolen and worsted than shoddy, cotton or jute yarns. Care must be taken to remove from the steam pipes under the floors all the fly and bits of yarn which may accumulate thereon. It is not advisable to have lights in dry rooms. Lights become especially hazardous when shoddy yarns, spun with low grade wool oil or heavy black petroleum oils are used. It is a well-known fact that oils of this kind cannot be saponified and washed out before dyeing, and must, therefore, be present in the yarns when the latter are dried. The heat of the dry rooms soon evaporates the lighter products of the petroleum, and in a short time the dry house is filled with very inflammable vapors, which would be readily ignited if brought into contact with an open light.

The custom of filling the dry house with yarn in the evening and turning on the steam in order to do the drying at night, when the rest

of the mill is not in operation, is a very bad one. The majority of our dry house fires occur towards morning, and, as a rule, on damp nights, when the moisture of the outside air prevents the escape of the hot air through the ventilators in the roof, and when the person in charge has turned on a full head of steam to overcome the increased moisture of the air in the dry house.

Ventilators in the roof of the yarn dry house which, if closed, open automatically when a dangerous temperature is reached in the dry room, should never be omitted.

In the dyeing of raw stock, especially cotton, the question becomes changed, and even the best method is dangerous. This stuff will flash and spread in an instant, and before the hands employed have time to save themselves, everything is in flames. The apparatus for drying raw stock usually consists of a box closed at the top by a screen, over which the material is placed, a fan or blower, and the steam pipes for supplying heat. It is apparent that these may be put together and arranged in the following ways: Either the fan and pipes are in the box beneath the screen, or the pipes are outside and the fan under the screen, or the fan is outside and the pipes inside, or both are outside. The first arrangement is the poorest. In this case, the fan would draw the air from outside, force it over the steam pipes and into the stock; if a piece of cotton should fall on the pipes below it would ignite and impart the flame to the stock above. Besides, in all cases in which the fan is below the stock, the shaft and other working parts soon become covered with fuzz; this soaks up the oil with which such machinery must constantly be lubricated; should at any time the journals, from some cause, as by want of oil, become hot, the greasy waste becomes ignited, and the flames ascend to the stock. Hot journals, on all kinds of machinery, are by no means seldom occurrences; the skillful inspector may frequently have noticed by a test, although not very æsthetic yet practical, that by spitting on the journals of revolving cards, etc., how the saliva instantly vaporized into a cloud of steam; and the impatient traveler may often have wondered "what are they are stopping for," when the simple cause was a hot journal from an unoiled axle.

The second method of drying is better than the first, but is still subject to the latter objection; in this case, the steam pipes are above the stock, and the hot air is sucked through the stock by the fan (blower) beneath. The next is but the reverse of the foregoing, and is seldom employed.

The last is the best; in this case, the steam pipes are over the stock, while the fan sucks the hot air through the stock by a flue, which is connected with the box. A method often advised by some insurance men, but which I believe to be objectionable, is the following: The pipes are outside of the box, and on a lower level than the drying stock, the fan or blower being also outside and lower than the stock. The fan sucks the hot air from the pipes and blows it through a flue into the closed space under the stock. Now let us suppose that a thick layer of moist stock be laid on the screen, and observe the effect. The layer of moist stock will be almost impervious to a current of air, the hot air from the fan will be confined, cannot escape from the enclosed space below the screen, but the fan will continue pumping hot air into the box until very soon a dangerous temperature is reached.

There is also another mode of drying, but which, on account of the slowness of the process, is not much employed, that is by cold air. The cold air dryers consist of a chest and fan or blower like the foregoing, but instead of using artificially heated air, they force through the stock air from the room, at the same temperature as the surrounding atmosphere. These dryers are very safe; but, as before stated, on account of the slowness with which they work, are not much in use.

When steam coils are used much depends on the construction of the box enclosing the pipes. This box should be of iron. It is necessary to have an opening to the box to facilitate the cleaning of the steam pipes.

When air is sucked over the steam pipes, and then blown out through the stock, the air-opening in the chest containing the steam pipes should, in all cases, be provided with a wire screen to prevent particles of stock from being sucked into the chest. Such stock accumulating on the spaces between the hot pipes will soon char, and frequently, when the fan is started after a short stoppage, the air blast will ignite this charring stock and carry it into the chest, causing ignition of the fly which will always be found in the chest.

Special care must be taken to provide an escape for hot air after it has passed through the stock, and the idea of providing no escape for the hot air from the enclosed space, in order to keep the heat in to do good and rapid drying is erroneous. The air confined in the enclosed space, although hot, is so laden with moisture that, instead of helping the drying, it retards it. The hot, moist air must be got

rid of to insure rapid drying. Ventilation is absolutely necessary to rapid and safe drying. When ventilation is provided, dry, hot air will be constantly supplied to the stock, and the accumulation of hot air in an enclosed space will be prevented.

Systems so arranged that the fan takes the hot air from the enclosed space above the stock, and forces it over the steam pipes a second time, so that the same air is used over and over again, I consider not as safe as a system where the moist air is allowed to escape. The continued reheating of the air will soon raise its temperature to such a point that it will do the stock more harm than good. Dyed cotton dried in this way is likely to be very harsh to the touch, and very hard to work on the cards. The drying of raw wool is not by any means as dangerous as that of raw cotton. Nor is exhaust steam as hazardous as live steam.

The simplest and safest method of drying raw stock is, without doubt, the frame drying flat, either on the roof of some low building or on the ground. Stock dried by this method is uniformly dried. It does not show signs of baking, and works easily and softly on the cards, less oil being necessary, less fly being thrown off, and hence less hazard in the card room. The latter is a very important factor of safety in a mill where dyed cotton (black or brown being the most hazardous) is used on woolen machinery. The system of drying by cold air is similar in its effect on the stock.

Where certain dyed cloth or yarn is dried, special care must be taken to prevent spontaneous combustion of the same; especially those in which the required shade of color has been produced by chemicals which absorb oxygen from the air, forming new compounds which produce the desired shade. The warmer the material comes from the drying cans, the less heat by slow combustion or oxidation is required for it to reach the ignition point at which it starts into active combustion; or when it is tightly rolled or densely packed the heat produced by the chemical action is not conducted away as readily as when exposed to the free circulation of the air, and thus accumulating soon reaches the ignition temperature of the mass. Fires of this nature have been caused by materials colored with browns made from catechu, cutch, gambier, or terra Japonica; iron buffs, indigo blue, and cloth prepared with oil for Turkey red; and even, though but seldom, in logwood and iron blacks; and more frequently in blacks made from aniline and its salts. Spontaneous combustion can be prevented by

cooling the goods thoroughly as they come from the drying cans and submitting them to the action of the atmosphere on all sides, they should never be piled in quantity or put up in rolls until these precautions have been taken. Sized goods are not as apt to ignite spontaneously as those unsized; but such cases do take place and are especially apt to occur where much tallow has been used in the size, since animal fats are prone to ignite damp goods spontaneously. Fires have been caused by supposed well-cooled goods being piled over night; all goods received from drying cans before closing in the evening should be placed in a fireproof room for the night, which, in order to secure frequent inspections, should be one of the watchman's stations, and should be provided with automatic sprinkler's and steam jets. When the steam supply pipes are properly hung (free from wood work) and when proper ventilation is provided, there is no special hazard connected with a steam drying cylinder, either when drying piece goods or warps.

Especial care should be exercised in singeing. Goods should not be rolled or piled in quantity before being well cooled, and examined for glowing particles which may have remained in them.

Cloth, when woven of yarns spun with wool oil containing low test petroleum gives off dangerous vapors if subjected to a high temperature on the cylinders. I would, therefore, advise to have no artificial light in inclosed rooms where this operation is carried on.

Tentering machines, both horizontal and upright, extending through one or more floors, when properly put up are not very hazardous. The steam pipes must be frequently cleaned off to remove all fly which will accumulate on them, and when the tentering machine is in an inclosed room, ventilation is as necessary as in every other process of drying.

As before stated, chlorate of potassium is now much used in the preparation of aniline blacks, which are considerably used in print works. The danger of potassium chlorate may best be illustrated by a little experiment.

Before you, on this table, I have a mixture of chlorate of potassium and finely powdered sugar. If I add but a drop of sulphuric acid to it, the same will ignite and be destroyed in a very short time.

[This experiment was then carried out.]

The reason for this is that the sulphuric acid, being a highly hydroscopic substance, unites with the water of the sugar, thereby charring or burning it, while the combustion is fed on through the oxygen con-

tained in the chlorate of potassium; a substance which parts very readily with the oxygen it holds in chemical combination. The terrible explosions and fires which from time to time occur in candy manufacturies, manufacturing chlorate of potash drops, may now no longer be a mystery to you, as they have been, to many experts, consulted at the times of occurrence.

PICKING.

After the raw stock has been properly dyed and dryed it must be willowed to remove the dirt; picked to reduce the knotted and tangled fibres, and mixed in proper proportions to facilitate the work on the cards.

The picking of the stock is justly considered the most hazardous operation in a mill.

The danger of the picker is the possible presence of foreign particles, such as stones, nails, etc., in the stock, coming in contact with the rapidly revolving cylinder of steel prongs, causing sparks and fires.

The hazard is proportionate to the inflammability of the stock. The willow, owing to its slow motion, and to the size of the teeth, which are frequently of wood, is not as hazardous. On the contrary, willowing the stock before picking it reduces the hazard materially, since most of the dust and foreign substances will be removed.

The mixing picker is the most hozardous, since the various grades of stock are passed through it at one time, the hazard being further increased by oiling the stock. Saponifying the oil reduces the hazard. This is done by adding either ammonia, potash or borax to the oil. Where the largest percentage of the mixing is cotton, a cotton-spreader is used, which is quite as hazardous, owing to the nature of the stock. Frequently a cotton-opener is used. This machine has caused so many fires that some managers have returned to the slower but safer process of "opening" the cotton by hand or by a willow before feeding it to the spreader.

In no case should open lights be permitted in picker rooms. Even inclosed lanterns will be a source of danger from the possible ignition of dust, which may accumulate on the top of the lamps, and which, igniting, may drop into a pile of loose stock. A light set in the wall provided with a heavy brass plate flush with the inside wall, and arranged to be lit from the outside only, is a very safe light for a

picker room. Incandescent electric lights when properly installed are excellent for picker house lighting.

Manufacturers frequently use their clean waste as a part of their "mixing." Where soft waste alone is used, no additional hazard is added to the picker room. Should, however, hard waste be used, a hard waste picker becomes necessary; this is one of the most hazardous pickers, equal in danger to the rag picker, which it resembles in construction. Careful managers, cognizant of this fact, do not pick their own hard waste, but send it out to be picked at shoddy mills.*

When a picker strikes fire, the burning stock will naturally be blown into the loose stock collected in the picker-box, hence the construction of this box is a very important point. In mills in the vicinity of Philadelphia, this box varies with the nature of the stock used, when pure wool only is used, the picker-box is often dispensed with. Where rags are picked, it is generally fire-proof. A substantial picker-box is preferable with any kind of stock. The best construction for the purpose is undoubtedly a brick chest with brick-arched ceiling with an iron-lined door at one side and an iron-lined slide to close the opening in front of the picker in case of an accident. An opening beside the door, which should be always closed when not used, is necessary for the passage of the air-blast. This opening can be readily made "fire-tight" by covering it with good strong wire-matting of close mesh. In place of this opening I would suggest a brick flue passing out of the roof of the picker-house; which can be protected from the rain, and will act as a chimney in case of a fire, being a natural outlet for smoke and flames without endangering the remainder of the picker-room. The only loss then will be the burning of the stock in the picker-box, at the time the picker strikes fire.

The flue from the picker to the dust-box, which should, in all cases be outside of the building (in some instances the dust-box is in a corner of the basement of the main mill) is best made of sheet-iron.

An undetected fire mouldering in the dust-box would soon find its way through a wooden spout into the picker-room after the picker is stopped. A light iron plate at the end of the metal spout so hung that it would be kept open by the air-blast when the picker is in operation and closed by its own weight when the picker is stopped, would be an efficient cut-off for a fire starting in the dust-box.

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* I am indebted to Mr. C. A. Hexamer for much valuable information in regard to pickers and picker house construction, and have made copious use of his notes on the subject.

One of the most objectionable features in the usual construction of the picker-house is the size of the edifice. In the majority of mills the picker-room is also used as a mixing room. A trifling fire, when fed by a day's mixing and a week's stock in bales, will soon cause a heavy loss. The picker-room should be as small as possible, so that the temptation to make it a stock-room will be overcome. The mixing-room can be located in a separate room, separated from the picker-room by a brick wall and a good iron-lined door. Where the yard space is limited, the mixing-room may be built above the picker-room, An opening may be made in the fire-proof ceiling of the picker-room· through which the stock can be lowered when ready for the picker. This opening in the ceiling should be provided with a fire-proof cover so arranged that it will always be closed when not in use. I would advise to have the stairway leading to the mixing-room in the second story built on the outside, so that there be no other opening in the ceiling, except the one closed by the fire-proof trap-door. If the brick flue from the picker-box is used, it must necessarily extend through the mixing room and out through the roof of the building. Steam pipes for heating the mixing-room are only safe when suspended from the ceiling. Many fires have occurred from spontaneous combustion of oiled stock piled against steam-pipes. The danger from this source varies with the nature of the oil used on the stock.

When "phosphor bronze" came into use some years ago, Mr. Edward Atkinson suggested the substitution of phosphor-bronze for iron whippers in the beater, as these would be less apt to produce sparks on coming in contact with foreign matter; and had an experimental picker manufactured, of which on one-half of the beater, ordinary whippers of Norway iron were used, and on the other half, those made of phosphor-bronze. Mr. Woodbury describes the results of experiments made with it as follows: "When the picker was in operation a number of pieces of iron were fed in, and a shower of sparks was emitted from the iron, but not from the 'phosphor-bronze' beaters; pieces of hard steel were substituted for the iron fed in, but with the same result. Phosphor-bronze whippers have been used in the same beater with Norway iron whippers for eighteen months; at the end of that time, the iron whippers had worn into the steel rods to which they were hinged, while there was no perceptible wear between the steel rod and the phosphor-bronze whippers. The working edges of the phosphor-bronze whippers were sharper than those of iron. The

results of extended investigations in the merits of this alloy show that it is superior to iron in safety, durability and efficiency."

CARDING.

The stock having been picked is now ready for the cards. The object in carding is the cleaning of the stock of dirt and foreign matter which may have remained after the picking, and to "card out" the short fibre of the stock, at the same time placing the various strands in parallel layers to facilitate the subsequent spinning. Cards are generally arranged in sets of three, and occasinally, of two and four.

A card consists of a large cylinder from three to four feet in diameter covered with card cloth (leather or rubber strips perforated by numerous steel wires of equal length), and of a number of smaller cylinders from six to eight inches in diameter. The smaller cylinders revolve in opposite directions to the large one; that known as the "fancy" revolving very rapidly. Where cotton or shoddy is used, the fancy should in all cases be provided with a metal cover, so that the short fibre carded out may be prevented as far as possible from flying about. The rapid revolution of the fancy makes it necessary to keep the journals of this cylinder well oiled. Carelessness in this respect has caused many card-room fires.

The hazard of the card-room consists chiefly in the accumulation of the particles of stock carded out, which, on account of their extreme lightness, fill the air of the room, and in settling, cover everything with a very inflammable substance usually known as "fly." A general rule is, the poorer the grade of stock, the greater the amount of fly created, hence the greater the hazard of the card-room. Wool only, when run over the cards, does not create much fly. When cotton or shoddy is mixed with it, the amount of fly is greater; when cotton alone, especially dyed cotton is run over woolen cards, the accumulation of fly, and hence the danger from fire, is greatest.

No doubt many of you have heard of the terrible explosions and fires which from time to time occur in flour mills. The reason for this is that when any organic substance, such as flour, is finely divided and mixed with air, it will, on coming in contact with a flame, be almost instantaneously ignited; the products of combustion being gases of many hundred times the volume formerly occupied by the dust, and these on expanding, create explosions.

If we enter a carding-room, in which cotton is worked over open

woolen cards, we find a condition of things almost analogous to those in a flour mill. We here have the entire air filled with a finely divided organic substance which, under certain circumstances is even more explosive and liable to ignite than finely divided flour. The only reason that we have not the severe explosions, for we frequently have the almost instantaneous fires, that we have in flour mills, is that the card-rooms are, as a rule, large, and the gases caused by the almost instantaneous ignition find means of exit without causing explosions. While in flower mills we have numerous enclosed spaces, such as smutters, mill boxes, elevator boots, etc.

A substance becomes the more inflammable, the greater its affinity for oxygen, thus the combustibility of a fibre increases directly with the avidity it has for the oxygen of the air. If, therefore, in the processes of dyeing, the property of uniting readily with oxygen has been imparted to the fibre, the finely divided fibres, commonly called flies, are more apt to ignite. It is for this reason that fibres dyed with certain chemicals which absorb oxygen are much more hazardous than the ordinary raw stock. Cotton, the purest form of cellulose in nature in its treatment with chemicals, required for the production of some colors, undergoes a change of state resembling gun cotton.

You will, by this time, have perceived the reason why the so-called mixed mills are so much more hazardous than the ordinary pure stock mills; the reason being that in mixed mills cotton, and frequently dyed cotton, is worked over open woolen cards, creating a tremendous amount of fine, extremely combustible and explosive cotton fly.

In order to test the explosiveness of different dusts, I have constructed an explosion apparatus.

The questions to be determined for every kind of dust are at what degree of humidity it will cease to explode, how finely divided each kind of dust must be in order to explode; and the determination of the temperature at the time of explosion. [A large drawing of the apparatus was shown.]

The apparatus consists of an ordinary kitchen boiler, such as are used for heating water, with its top taken off. This top may be closed by a ring over which tissue paper has been pasted, and the ring is tightly screwed on as shown in the figure. In the interior you will perceive two hooks, one being for the reception of a thermometer by which the temperature of the atmosphere in the interior may be obtained before exploding the dust, and the other for a hygrometer, by which

the humidity of the contained air is determined. In the bottom of the apparatus a gas pipe is inserted, the jet being lighted (in order to secure greater safety) by electricity from a distance. On the upper end a funnel, with a blower is attached, by means of which the finely divided dust may be blown in. In order that I may not be dependent on the surrounding atmosphere for the temperature and the humidity of the contained air a small boiler is in connection with the apparatus, by means of which steam may be blown into the interior, and thereby any degree of humidity produced that is desired; while the temperature may be regulated by the gas jet burning in the bottom.

The manner of using the apparatus is as follows: After the temperature and humidity of the enclosed air has been determined, the thermometer and hygrometer are removed, the cap with the tissue paper cover is tightly screwed on, and the dust blown in. When a short time has been allowed the dust to mingle with the contained air, the gas jet is lighted by means of electricity, and the explosion occurs.

I am now engaged in making numerous experiments with various kinds of organic dusts, which are produced in different technical occupations; and will publish the results of my experiments, when they are completed.

SPINNING.

From the cards the stock is taken to the spinning frames, and this department is one of the most prolific sources of fires caused by friction, especially in the mule heads, which should be kept thoroughly clean and lubricated. The ends of the carriages next to the head should be well closed, with an opening just large enough for the drum cords. When fires originate in mule heads, these are transmitted throughout the machine with almost instantaneous velocity, unless the carriage is kept very clean and clear of oily waste.

OILS.

Statistics of fires among New England mills have shown that 37 per cent. of fire losses are caused by spontaneous combustion, and hot journals from friction caused by bad oils. A good lubricating oil should not be acid nor strongly alkaline; nor should it, through variations in temperature, become acid or alkaline. Most vegetable and animal oils, when they are exposed to high temperatures, such as that of superheated steam, are decomposed, and acids are set free; as they

are composed of stearic, oleic and palmitic acids combined with glycerine. These free acids corrode the surface of the metals, making them rough, and forming compounds which are the very opposite of lubricants. Their use, therefore, for journal boxes, in hot weather, or where they become heated, is to be deprecated, for at high temperatures they combine with the oxygen of the air and decomposition results.

A mineral oil never becomes acid from any decomposition, and will not corrode the metals to which they are applied. When these are mixed with glycerine, they form a very good lubricant. The great danger in buying mineral oils is that large quantities are annually put into the market far below the necessary flash test. These oils should be prepared by fractional distilation at a temperature not below 500° F. When mineral lubricants with a low flash test are used, they are exceedingly dangerous, as, on becoming heated in the journal, the volatile parts go off as vapors, making it dangerous to examine a journal or any other part with an open light. In order that a mineral oil should be a good lubricant, it should not flash under 300° F.; should not give off more than 5 per cent. of volatile matter at 140° F. in twelve hours; should be free from grit; and should contain no free acids or alkalies.

To determine the flash test accurately, an instrument too complicated for the use of the ordinary manufacturer is required; but he may, for his purpose, approximately determine the same by pouring the oil in a flat dish, which is placed on a plate containing dry sand, to which heat is applied (so as not to apply the heat to the oil directly), thus causing a gradual heating of the oil. A thermometer is then inserted some distance from the bottom of the dish, and the rise of the temperature noted. A lighted taper is then moved over the surface of the oil, care being taken not to touch it. If the vapors given off by the oil flash below 300° F., the oil is to be condemned, and not used as a lubricant.

To determine the amount of volatile matter in an oil, the sample must be carefully weighed in a fine scale and then exposed to a temperature of 140° F. for ten or twelve hours; then cooling it, reweigh it. The loss in weight will be the amount of volatile matter given off in that time. If the loss be more than five per cent. the oil should not be used.

In order to determine the amount of solid foreign matter, such as grit in oil, a sample very near the bottom of the barrel (as the greater

gravity of the solid material will cause it to gravitate to the bottom) should be taken and placed between two clean glass plates and then rapidly rubbed together, when the grit will at once be detected.

Acids or alkalies in oil may readily be detected through litmus paper. If blue litmus paper is dipped into an oil containing acids, it will be colored red, while red litmus paper is turned blue when dipped into an oil containing alkalies. Any oil giving an acid or strong alkaline reaction should be condemned.

Mineral oils sometimes give acid reactions, not from any decomposition of the compound, but from the sulphuric acid used in the processes of manufacturing it, which has been imcompletely neutralized with caustic soda. If the amount of soda has been too small, an excess of acid remains; while in the presence of an excess of soda, a residual amount of soda will remain, which also has a bad influence on the metal bearings.

A test for sulphuric acid can readily be made by mixing a sample of the oil with water, and after well shaking it, allowing it to stand until the oil separates from the water, which is then poured off. On account of its hydroscopic properties the sulphuric acid will have united with the water. If now a solution of a barium compound be added to the water, a white precipitate of sulphate of barium will at once be caused, if sulphuric acid be present in the oil. In order to make the test sure, as there are other acids which throw down a white precipitate, the precipitate must be treated with strong nitric or hydrochloric acid, and if it remains unchanged, sulphuric acid is contained in the oil.

If the litmus paper shows the presence of alkalies, these may be tested by treating the oil with water, as before described, then evaporating the solution to dryness, and placing the residue in the colorless flame of a Bunsen burner. Sodium will give an intensely yellow flame, if potassium be present a beautiful violet flame will be produced.

Adulterations of animal oil or mineral oil may be detected by adding concentrated sulphuric acid, when the animal oil will be charred, forming black rings in the sample. Vegetable or animal oils can also be detected by adding an alkali to the sample, thus causing these to saponify; as mineral oils have not the property of saponification. Oils are frequently adulterated with cotton seed oil, which is prone to ignite waste spontaneously.

SPONTANEOUS COMBUSTION.

Numerous fires are caused by the so-called phenomenon of the spontaneous combustion of waste. Spontaneous combustion of oily rags or waste is caused by a rapid absorption of oxygen from the air. Oils which have a great avidity for oxygen being the chief causes. By a number of experiments, it has been shown that when vegetable or animal oils contain one third or over mineral oil, they will not ignite waste impregnated with them, spontaneously.

I have not time enough this evening to go into a lengthy discussion of spontaneous combustion and its causes, but must refer you to my work on "Spontaneous Combustion," which will shortly appear, in which this branch of the subject is treated in detail. I will merely give you the experiments of Dr. James Young, which are before you.

TEMPERATURE OF CHAMBER FROM 130° F. TO 170° F.

Boiled linseed oil on cotton ignited in				1¼	hours.
Raw	"	"	"	4	"
Lard	"	"	"	4	"
Colza	"	"	"	6	"
Olive	"	"	"	5	"

Seal oil and mineral oil, equal parts on cotton would not ignite.

TEMPERATURE OF CHAMBER FROM 180° F. TO 200° F.

Colza oil on wool ignited in		6	hours.
Olive oil on cotton	"	2	"
Olive oil on wool	"	7	"
Seal oil on wool	"	3	"
Whale oil on jute	"	9	"
Whale oil on cotton	"	3	"
Cotton seed oil on wool	"	5½	"

The following were not ignited by twenty-four hours' exposure in the hot air chamber:

Olive oil and mineral oil, equal parts on cotton.
Colza oil and 20 per cent. mineral oil on wool.
Seal and mineral oil, equal parts, on wool.
Whale and mineral oil, equal parts, on jute.
Cotton seed oil and 20 per cent. mineral oil on wool.

And the following table showing the results of the experiments of J. J. Coleman:

	Entered into combustion after	At a temperature of
Cotton waste saturated with whale oil	3 hours.	165° C.
Cotton waste saturated with olive oil	4 "	177° C.
Olive oil and 20 per cent. mineral oil	8 "	177° C.
Mineral and olive oil, equal parts, no change after lapse of 26 hours, after 12 hours, temperature 95° C		
Wool waste and seal oil	3 "	194° C.
Wool waste and whale oil	3 "	188° C.
Wool waste and cotton seed oil	5 "	178° C.
Wool waste and olive oil	7 "	177° C.
Wool waste and refined rape oil	6 "	177° C.
Wool waste and crude rape oil	8 "	163° C.
Wool waste and cotton seed oil with 20 per cent. mineral oil; seal and mineral oil, equal parts; olive and mineral oils, equal parts, unaltered after lapse of 26 hours.		
Jute waste with whale oil	8 "	180° C.
Jute waste with whale oil and mineral oil, equal parts, unchanged after 26 hours.		

I am at present engaged with a number of experiments in spontaneous combustion, which I hope will, by the apparatus used for experimenting, prove more accurate than those formerly made with cruder apparatus.

[A large drawing of the apparatus was shown.]

The figure before you illustrates the device. Inside of the upper half of a strong metallic box, divided in two by means of a metallic partition, a wire cage containing the material saturated with the oil to be experimented with is placed. The wire box is surrounded by an air space on all sides, being, for this purpose, placed on legs, so as not to be in direct contact with the metallic surface of the partition. The lower half of the subdivided box is connected with a small boiler in which steam is generated (by means of a Bunsen burner), and the steam entering the lower half of the box produces an equalized temperature in the upper division, while the material to be experimented with, is surrounded and submitted to the action of the air on all sides. A thermometer is inserted in the upper partition, by means of which the exact temperature in it may be noted. In order to increase the temperature to any desired degree, the steam which passes through a strong pipe from the boiler to the lower half of the box, may, in its passage be heated to any desired temperature by applying a Bunsen

burner to the pipe. In order that the rise of temperature in the mass before ignition may be noted, and also the exact time when ignition has set in, a number of thermostats, set for various temperatures, are placed in the mass experimented with. These, as well as a conductor with a fusible solder link in it, form electric circuits, and are connected with electric clocks. As soon as the temperature corresponding to each thermostat is reached, the contact is broken, the clock stopped, and the interval between starting the experiment and this time can be noted, while the time of ignition of the mass is indicated by the stopping of the clock placed in the circuit containing the fusible solder joint. That the amount of humidity (which plays an important role in the spontaneous ignition of waste) may be varied, a small steam boiler, like the one described in the explosion apparatus, is connected with the upper chamber, and any desired quantity of steam may be blown in the same, and the humidity of the contained air altered at will.

I before spoke of the importance of the microscope in regard to testing textile processes, I will now show you a series of microscopic slides thrown on the screen, greatly enlarged. Fine fibres, which ordinarily are hardly visible to the naked eye, will be seen projected on the screen four, and on the rear wall eighteen inches in diameter. This is accomplished by means of Mr. Holman's excellent lantern, a one-tenth immersion lens being used (the object and the lens being both immersed in glycerine). The entire light of a large electric arc lamp being concentrated through a small aperture not much larger than the head of a pin, and thrown on the screen.

The following fibres were then shown on the screen:

1. Cotton fibre fresh from bale.
2. Cotton from bale dyed with analine black.
3. White carded on flat cards.
4. Gray 1 and 2 mixed, carded on flat cards.
5. Gray 1 and 2 mixed, carded on worker and stripper cards.
6. White (3) spun in three thread loosely.
7. No. 3 dyed light blue spun in 3 loosely.
8. No. 3 dyed deep blue spun in 3 loosely.
9. No. 3 badly dyed red, spun in 3 loosely.
10. Sea Island spun white in six cord, tight.
11. Sea Island deep blue in six cord, tight.
12. Sea Island badly dyed red in six cord, tight.

13. Flax (raw fibre).
14. Jute (fibre).
15. Sheeps wool donskoi. (The scale-like structure was shown with great clearness and size.)
16. Silk fibre reeled and dyed.
17. Fabric (silk poplin) wool, silk and linen.
18. Fabric (all silk).
19. Wool waste.
20. Extract of wool.
21. Silk noils.

MILL ARCHITECTURE.*

The first principle in architecture, and foremost in buildings intended for manufacturing purposes, is utility; and all other considerations are subservient to it. The elements of Vitruvius, *Firmitas*, *Utilitas*, *Venustas*, stability, utility, beauty still hold good. That mill building is the best which is best suited for its purpose, and that architect is most expert, who exactly knows what changes in his plans are required for every department of manufacture. I, of course, do not mean to say that a mill should be erected in bad proportions "a hideous mass of stone, an eyesore to mankind;" on the contrary an architect shows his superior skill if he, notwithstanding the small amounts usually allotted to decorative purposes, and the fetters which that tyrant utility places on him, is still able to erect an evenly proportioned well looking building. The higher a building is, the better should be its construction. The simplest of all rules of building, to construct a building safely and solidly, is frequently neglected. The great principle in fire constructions is to divide the building into numerous parts, and then to construct these parts in such a manner and of such a material that a fire originating in any one part may be restricted to it. The main great divisions into which a manufacturing place is divided are the stories. It then becomes our problem to construct each story so that a fire starting in one, may be restricted to that story; so that smoke, fire and water used to extinguish the flames, may not harm other stories and their contents. To arrive at this result there must be no openings in the floors; that is, the elevators and stairways must be outside of the main building, and belt and other openings must not break the floors. In order to accomplish this we must place stairways and elevators in separate stairway and elevator houses, the walls of which should be of sound brick and of sufficient thickness. The walls should only be broken by the doors leading into the separate stories. These doors should be iron-lined on both sides, and should be self-closing (either by a spring or weight) the doors being held open by a piece of fusible solder, which melts at any considerable rise of temperature.

The practice of putting in wooden sills, and lining them on top with

* A lecture delivered before the Franklin Institute, December 17, 1884.

sheet iron, is to be deprecated, as the woodwork of the adjoining floors forms a juncture with the wooden sill, and a fire will be transmitted underneath the iron. The elevator openings in the elevator house should be self-closing so that a double security—the elevator doors and the doors leading into the main building—may be had. Especial care should be taken to extend the walls of the stairway and elevator house through the roof of the main building, thus cutting the trussing and timbering of the roofs, so that a fire may not be transmitted through the woodwork of the roof. A good-sized ventilator should be placed over the elevator house, so that in case of fire the smoke may escape through this—like a chimney—thus making it easier for firemen to see and work, and for employés to escape from the building; this is of so much importance that the Philadelphia Fire Underwriters' Tariff Association has made it a requirement in hotel buildings. Great care must be taken to keep the bottom of elevator houses free from waste and rubbish as this by igniting either spontaneously, or by a burning object being thrown into it, has caused many fires. The safest construction for a stairway house is that used at the Ontario Mills, of the Arrott Steam Power Mill Company, in which the stairway house is entirely cut off from the main mill by blank coped walls without any direct communication with the mill, the communication between the mill and the stairway house being effected by means of iron porches on the outside of every story.

FLOORS.

The safest floor, which has for a long time, been used in fire-proof construction, is one consisting of brick arches, sprung between iron girders. In order to be of practical value, the spans must not be too large, as iron, which is an excellent conductor, soon warps by unequal expansion in case of fire, and is apt to throw out the intervening arches. When spans are large, the intervening arches readily drop out of the girders which hold them, and thus entire buildings, which were considered fire-proof have been totally destroyed. Care must, therefore, be taken to cover all exposed iron surfaces with a poor conductor of heat.

A construction much used in France, which has proved successful in many cases, is an iron girder with concrete arches, the arches being formed by means of moulds and held together with tie rods until dry. When good concrete dries, it becomes as hard as stone, and being an

excellent non-conductor of heat, when properly erected, so as to surround the entire iron work, keeps the iron from becoming heated and and warping.

Iron girders have also been used in conjunction with terra cotta, and with the so-called terra cotta lumber. Terra cotta lumber is a material manufactured from clay and saw-dust. The clay being mixed with saw-dust is formed into the required shape, then dried, and burned in a kiln; the organic part is destroyed, and a porous mass remains which may be worked with a chisel like lumber. Tests which have been made with this material in New York have proved very satisfactory.

[A number of slides were then shown, illustrating the manner in which these different materials are used and erected.]

A concrete floor, when made with good cement, is, next to a brick arched floor, the best known. This snbstance forms into one solid hard rock-like mass, and those who have seen the works in France, where entire churches and aqueducts have been built with it, will no longer doubt its efficiency. It may be well remembered how at the great fire of the Jayne building, at Philadelphia, an ordinary mortar floor saved the second story. The problem then is, "How can we construct a cheap, light and effectual floor?"

A solid three-inch plank floor, laid flat, tongued and grooved, with one and a quarter inch flooring boards on top arranged for flooding, is the usual manner in which the floors of mills are now laid. These can be much improved if, between the plank and flooring boards, a layer of good mortar or concrete is inserted, making an excellent, slow burning floor. Asbestos paper, or better the thicker asbestos bill board, is sometimes used with good effect, between the flooring boards and plank; although it has been claimed by some that the asbestos is hydroscopic and attracts the moisture from the flooring, causing the boards to rot. I have never experimented to any extent with this material, and cannot therefore, express an opinion on its merits or demerits.

All floors should be arranged for flooding. This is accomplished by raising all sills and other openings through which water may escape. A floor arranged for flooding, when otherwise well laid, is one of the best means for restricting a fire from extending from one room to another, for, as soon as the fire appliances, such as sprinklers, hose, etc., are turned on, there is, in a very short time, a pond of an inch or an inch and a half deep formed on the floor, which prevents the floor from

igniting; at the same time, a rise in temperature vaporizes the water on the floor, causing the formation of steam, which tends to extinguish the fire.

We are now fairly well protected from fire, smoke and water from above, how then are we to protect the wooden ceiling in case of a fire from below? The simplest but costly method would be to iron-line all wood work; another would be to cover the wood work by a so-called fire-proof solution. I have experimented with all solutions which I could ascertain; but as I have not time to go into details on this part of the subject I must refer you to a series of articles in the *Spectator* in which I described the results of my experiments.

It is well known, that several preparations exist which render wood mpervious to heat, and, at the same time, increase its durability. Some of the solutions have been tried on a large scale, and have proved themselves successful wherever used. Although these measures are cheap, and their success demonstrated, they have, with few exceptions, as for example at Frankfort-on-the-Main, the Hof Theater at Berlin, and several German manufacturies, not been employed. Perhaps the general public will, in view of those frequently recurring catastrophies, at last comprehend that even the retardation of the combustion of wood-work would be of inestimable value in securing immunity from fire, and that the spreading of flames would be greatly retarded if, instead of burning rapidly, as dry wood will, it slowly chars into coal. The nature of wood makes it an easy matter to change it into a state frequently, though incorrectly, called fire-proof! On account of its porosity, a solution applied to its surface sinks deeply into its pores, thereby attaining a firm hold, and on account of its rigidity exposes the covering to abrasion only. Care should be taken where such solutions have been used, to replenish them, from time to time, so as to keep the wood entirely covered.

Asbestos paint is a clean and excellent coating for wood, or better still, the thicker asbestos concrete. These substances act like true paints, adhere tightly to the wood, give protection against high temperatures, and do not readily rub or chip off. It has but one objection; that is, its solubility in water; it cannot be used in places exposed to the action of water, but for most interior purposes this is no material objection. Great care must be taken in purchasing this article and should always be tested before being used, as so much of the so-called "asbestos paint" which is sold is entirely worthless.

Ordinary whitewash is a cheap and excellent coating against fire. It adheres tightly to the wood, impregnating it to a certain extent and when frequently replenished will form an excellent coating.

Wood, impregnated with ammonium sulphate, transforms it into a condition which has frequently, but incorrectly been termed "fire-proof." Ammonium sulphate keeps the wood from burning with a flame, and only those parts which come in direct contact with fire are charred, but the parts in contact with flames, even in charring, will not transmit the fire any further. Numerous experiments which I have made with ammonium sulphate, have, in every instance, proved successful; even at the severe fire of a large chemical works where parts of the wood impregnated with this substance, in direct contact with the flames, were charred, and adjacent parts remained intact.

When ceilings are plastered, this should be done with wire netting and the plaster laid on it, especial care being taken that the netting follows the outlines of the ceiling closely, so that no hollow spaces occur. The great principle is to avoid all hollow spaces, between which dirt may accumulate and fire travel. The so-called "sealed" ceilings, that were formerly in vogue, should always be avoided.

GIRDERS.

Girders should be solid. When it is necessary to use compound girders, they should be tightly bolted together, so as to leave no intervening spaces. In storehouses, etc., where there is but little vibration, girders may be inserted in the wall by placing them either on brackets or a short distance into the wall with bevelled edges, without any further anchoring. In mills, where the amount of vibration is great, Woodbury advises to securely bind the beam to the wall by embedding in the masonry a flat cast-iron plate with a transverse fin upon each side near the end, one to secure the plate in the wall and the other in a groove across the under side of the beam, firmly secured by wedges driven in at each side of the fin. The bricks in the wall for about five courses above the beam should be laid dry, and the upper edge of the beam at the end slightly rounded and an air space being provided at each side of the beams.

Under no consideration should the old-fashioned anchorage of fastening the girder on the outside of the wall with a large anchor plate be used. As when the beams burn through the leverage brought to bear on the wall will overturn it.

[Numerous slides were here shown, illustrating the different modes of anchorage and the construction of girders.]

WALLS.

Brick is the best material for fire construction. It stands long after granite has disintegrated and marble has been burnt into lime. Iron fronts are to be deprecated, and especially such shells of iron as are frequently erected, without even a brick filling. Sandstones when the sand particles are held together by a good binding material are serviceable, but those in which the sand particles are held together by lime should not be used in building. Granite is a very poor stone for fire construction, as its inter-molecular spaces contain water, which, on being heated vaporizes into steam, causing the disintegration of the granite. Marble is also a poor material to use, as, on becoming heated, it is decomposed, carbonic acid and burnt lime being formed. For this reason, lintels over doors, windows, etc., should never be made of marble, granite, or poor sandstones. Preferably, a brick arch should be sprung. Good brick buildings have frequently been destroyed by having poor stone lintels over driveways and so on, which were destroyed by fire, causing the falling of the brick wall. Where further ornamentation is required, terra-cotta ornaments may be used; these are now manufactured in all shapes and varieties.

CORNICES.

Where cornices are used, these should be of brick or terra-cotta. Under no circumstances should "wood-boxed" cornices be used, as these transmit the fire from one part of the building to the other, and for this reason, even hollow metal cornices are objectionable, as they form flues along which the flames travel.

COLUMNS.

The best column to stand in case of fire is a good hard wood column, without taper, bored near the top and bottom so as to prevent dry rot, lined with sheet iron or any other metal, or covered with a good protecting substance. Of all columns, those of exposed cast iron are the poorest. These, on even a slight rise of temperature, readily disintegrate, especially when water is poured upon them. Wrought iron, on being exposed to high temperatures, expands and warps. Exposed

iron, therefore, is the most untrustworthy of all materials for column construction.

In order to protect iron columns from surrounding temperatures numerous devices have been devised to cover them with non-conductors. The columns constructed by Mr. Wight, of Chicago, are excellent for this purpose. Terra-cotta lumber has been used for this purpose, as well as plaster and mortar. Ordinary lime mortar or concrete is preferable to a gypsum composition, as this readily corrodes the iron. Care must be taken to surround all parts of columns exposed to abrasion, such as the base with a hood of wood.

[Numerous illustrations of improved columns were then shown.]

ROOFS.

There is no part of a building which is put to such a severe wear and strain as the roof; being, at certain times of the year, exposed to high temperatures on the inside, and to very low temperatures on the outside. A good roof should be of three inch plank, tightly fastened together, protected on the inside with sheet iron or other metal, asbestos concrete, or with a wire netting tightly fastened on, so as to leave no hollow spaces, and the plastering placed on this; a good metal covering being placed on the outside with nails counter-sunk and stopped with putty. Slate makes a poor covering, as by a rise in temperature it readily disintegrates.

FIRE DOORS.

There are few parts in fire construction which are of so much importance, and generally so little understood, as a fire door. Instances of the faulty construction of these, even by good builders and architects, may daily be seen. Iron doors over wooden sills, with the flooring boards extending through from one building to the other, are common occurrences. We frequently find otherwise good doors hung on to wooden jambs by ordinary screws. Sliding doors are frequently hung on to wood work, and all attachments are frequently so arranged that they would be in a very short time destroyed by fire, and cause the door to fall. In case of fire, a solid iron door offers no resistance to warping. In an iron-lined door, on the contrary, the sheet iron, which tends to warp, is resisted by the interior wood, and when this burns into charcoal, it still resists all warping tendencies. I have seen even heavily braced solid iron doors warped and turned after a fire,

having proved themselves utterly worthless. It is needless to say that when wooden doors are lined, they should be lined on both sides; but frequently we find so-called fire-proof doors lined on one side only.

Good doors are frequently blocked up with stock and other material, so that in case of fire they could not be closed without great exertion, or they have been allowed to get out of order, so that in case of fire they are useless. This has been so common that it has given rise to the jocular expression of insurance men, when they are told that a fire door exists between two buildings, "Warranted to be open in case of fire." The strictest regulations should exist in regard to closing the fire doors nightly. Frequently we find that although the fire door, and its different parts, are entirely correct, there are other openings in the wall which would allow the fire to travel from one building to the other, such as unprotected belt and shaft holes. That a fire door may be effective, it must be hung to the only opening in that wall.

The greatest care must be exercised to keep joists from extending too far into the wall, so as not to touch the joists of the adjacent building, which would transmit the flames from one building to the other in case of fire. A good stone sill should be placed under the door, and the floor thereby entirely cut. Sills should be raised about one and a half inches above the level of the floor, in order to accomplish the necessary flooding of the same. If stock must be wheeled from one building to the other, the sill can readily be bevelled on either side of the wall, allowing the wheels to pass readily over it. Lintels should consist of good brick arches. When swinging doors are used, they should be hung on good iron staples, well walled into the masonry, and the staples so arranged that the door will have a tendency to close by its own weight. The door should consist of two layers of good one and a quarter inch boards, nailed crosswise, well nailed together and braced, and then covered with sheet iron nailed on, or if of sheet tin, flanged, soldered and nailed. Particular care should be taken to insert plenty of nails, not only along the edge of the door, but crosswise in all directions. I have seen cases, in which nails had only been placed along the edges, where the entire covering had been ripped off through the warping tendencies of the sheet iron.

The hinges on these doors should be good strap hinges, tightly fastened to the door by bolts extending through it, and secured by nuts on the other side. Good latches, which keep the door in position when closed, should always be provided. In no case should the door

be provided with a spring lock, which cannot be freely opened, as employes might thereby be confined to a burning room.

Sliding doors should be hung on good wrought iron run-ways, fastened tightly into the wall. Wooden run-ways, iron lined, which we frequently see, are no good, as the charring of the wood in the interior causes them to weaken and the doors to drop. Run-ways should be on an incline, so that the door when not held open will close by itself. Care must be taken to have a stop provided in the run-way, so that the doors may not, as I have frequently seen them, overun the opening which it is to protect. Doors should overlap the edges of the openings on all sides. Large projecting jambs should never be used.

All doors contained in "fire-walls" should have springs or weights attached to them, so as to be at all times closed. Fire doors can be shut automatically by a weight, which is released by the melting of a piece ef very fusible solder employed for this purpose. So sensitive is this solder that a fire door has been made to shut by holding a lamp some distance beneath the soldered link and holding an open handkerchief between the lamp and link. Though the handkerchief was not charred, hot air enough had reached the metal to fuse the solder and allow the apparatus to start into operation.

These solders are alloys more fusible than the most fusible of their component metals. A few of them are—Wood's alloy consisting of:

Cadmium	1 to 2 parts.
Tin	2 "
Lead	4 "
Bismuth	7 to 8 "

This alloy is fusible between 150° and 159° Fahr. The fusible metal of d'Arcet is composed of:

Bismuth	8 parts.
Lead	5 "
Tin	3 "

It melts at 173·3°. We can, therefore, by proper mixture, form a solder which will melt at any desirable temperature.

Numerous devices for closing doors automatically have been conconstructed, all depending upon the principle of the fusible solder catch.

[Various automatic doors were then explained with stereopticon views.]

CONSTRUCTION OF PICKER HOUSES.

The proper construction of that hazardous part of a mill, the picker house, is of the utmost importance. Frequently we find picker houses, otherwise well constructed, with some fault in them which then endangers the whole. Glass transoms above iron doors, between the main mill and the picker house, may sometimes be seen, while large belt holes in the protecting wall are very common. These will readily convey fire from the picker room to the mill. It is difficult to protect belt openings by iron slides. It is therefore better to have power conveyed from the mill to the picker room through shafting. When journal boxes are set in the wall, but small apertures are required.

A frequent mistake in picker houses is to place the windows in the wall of the main mill above the picker house, unprotected by iron or iron-lined shutters. Picker houses are generally one story high, the flames striking upwards being thereby communicated to the mill. The ventilators and skylights in the roof of the picker house increase the danger from these sources. Windows in the picker house, facing the mill, may also frequently be found. These, if possible, should be dispensed with. If they are absolutely necessary, good iron-lined shutters should be provided, which must in all cases be arranged to close from the outside. Frequently enlosed gangways connect the picker house with the main mill. These should be constructed of corrugated iron, with good iron-lined doors at either end. If these are not arranged to close automatically in case of fire, they should be fixed so that they may be closed from the outside without entering the gangway. A great mistake, frequently made, is to store stock in the gangway, or allow waste and other rubbish to accumulate in the same. In case of fire, this will be a conductor for the flames to extend from one building into the other, before time may be found to close the fire doors.

Brick, stone or cement floors should be used in the picker house. Wooden window jambs and casings should not be used; while substantial iron, or, better still, iron-lined shutters, for solid iron shutters have the demerits of iron doors, should be hung over all openings, extending beyond the edges of the windows. A shutter should be constructed like an iron door, hung on good iron staples built into the wall, and always on the outside of the building. Shutters hung on wooden window casings will, of course, fall as soon as the wood work

is destroyed. Iron shutters should never be placed on the inside, as it is against human nature to remain inside of a burning building to close shutters.

CARD ROOMS.

The card room should be as large and well ventilated as possible. The ceilings should be high, and as few projections contained in the same as possible, as these will cause the fly to settle on them. The card room should be wide enough to allow the placing of the cards in sets side by side, with sufficient space between the sets to allow the cleaner to pass around them freely.

TRANSMISSION OF POWER.

All driving fixtures should be contained in separate houses, constructed like a stairway or elevator house, cut off from the mill by coped fire walls, as a fire will be carried from story to story through belt openings and boxes. Particular attention should be given to belt boxes, where they do exist, to keep them at all times scrupulously clean from waste fly and so on. Belt boxes should be provided with a good supply of automatic sprinklers. Objections have been raised to sprinklers by some, for the reason that should they be opened by accident the belts would be damaged by water. Mr. Edward Atkinson suggested that the belts should be enclosed in a glass chamber, and that automatic sprinklers should be placed outside of the glass. This arrangement, I understand, has worked well in practice.

All dangerous journals throughout a mill should be provided with automatic alarms, which give an alarm as soon as a journal becomes dangerously hot. One of the best, the Journal Thermostat of Whitaker, consists of a U-shaped glass tube, with arms of equal length, one of which is closed. The left arm contains a small amount of a volatile hydro-carbon liquid, and the remainder is filled with mercury. When the temperature of the journal rises beyond a certain point, the hydro-carbon is vaporized, and forces out the mercury, which, in collecting in the receptacle below, closes the electric circuit, which gives the alarm.

[Various slides were shown for further illustration.]

HEATING.

The old primitive method of heating by stoves is but little found in the better class of mills. Where these are used, care should be taken

that they are placed on metal, with good stove pipes, passing into chimneys, the stove pipes being tightly wedged into the wall, so as to keep them from disengaging and allowing the sparks to fall into the room. Under no consideration should stove pipes pass out of windows.

The safest system of heating is by hot water. In this case, the heat is produced by radiation from pipes filled with hot water, the same being heated in a boiler, preferably outside of the mill.

Steam is usually employed for heating in mills. Special care must be taken to have the pipes free from wood work, and away from all places where dust, dirt, waste and so on may accumulate. Steam pipes should be hung along the ceiling, about 24 inches below it, in preference to the old fashion, along the sides of the room, where stock and waste is frequently piled. The theory, so frequently advanced, that, if pipes be hung below the ceiling, the same amount of heat cannot be obtained as when they are hung along the sides, is erroneous. This table, which shows the results of a series of experiments made by Mr. C. J. Woodbury, demonstrates this fact.

Hourly thermometrical observations were taken in a room, 75 x 400 feet, supplied with five rows of steam pipes, against the walls near the floor, in the first instance, and in the second there were four rows of pipe around the room, two feet from the walls and hung the same distance below the ceiling, requiring only three-quarters as much pipe as in the first instance.

Mean Temperature of Hourly Readings.

Thermometers hung in centre of room.	Degrees Fahrenheit.	
	Pipes at side. Dec. 29 to Jan. 5.	Pipes elevated. Jan. 29 to Feb. 5.
Sixteen inches from ceiling	80·05°	80·80°
Midway	76·52°	76·90°
Sixteen inches from floor	77·08°	77·00°
Average	77·88°	78·23°

The reasons that steam pipes ignite wood are twofold. First, in case of superheated steam, we have a regular combustion going on; in the second case, with steam pipes containing steam, at the usual temperature, we have a secondary phenomenon of spontaneous combustion.

In the latter case, the steam pipes slowly dry the wood, the contained moisture being vaporized, and at last the wood assumes a state resembling that of charcoal; it is then that the glowing or the combustion, well known in the case of charcoal takes place spontaneously.

At a discussion of the French Academy, in 1879, this was brought out clearly. M. Cosson described an accident which had occurred in his laboratory a few days before. While the narrator was working in the laboratory, a portion of the boarding of the floor spontaneously took fire. The boards were in the vicinity of an air-hole, fed with warm air from a stove four metres away on the floor below. A similar accident took place two years ago, and in consequence M. Cosson had the boards adjoining the air-hole replaced by a slab of marble. The boards which now ignited adjoined the marble. The heat to which the boards were subjected was, however, very moderate, being only that of warm air at 25°C. Nevertheless, M. Cosson said the wood had undoubtedly been slowly carbonized. Being thus rendered extremely porous, a rapid absorption of the oxygen of the atmosphere had resulted and sufficient caloric was thereupon produced to originate combustion. The danger thus disclosed, said M. Cosson, is one to which the attention of builders ought to be directed. In the instance in question, M. Cosson was able to extinguish the fire with a little water, as he was present and witnessed its beginning; but had it occurred at night, during his absence, it would undoubtedly have completed its work of destruction. M. Fayé stated that at Passy, a few days before, a similar case of spontaneous fire, due to the action of the warmth from the air-hole of a stove upon the wood work, had occurred at the house of one of his friends.

Mr. C. C. Hine, editor of the *Monitor*, relates the following: "The Institute of Technology, at Boston, long ago decided upon the danger of steam pipes passing through and in contact with wood. It was shown that the wood, by being constantly heated, assumes the condition, to a greater or less degree of fine charcoal, a condition the most favorable to spontaneous combustion. This is so important and interesting a point that we may be pardoned for enlarging upon it somewhat in contrast to the brevity of the foregoing paragraphs.

"Steam was generated in an ordinary boiler and was conveyed therefrom in pipes which passed through a furnace and thence into retorts for the purpose of distilling petroleum. Here the pipes formed extensive coils and then passed out, terminating at a valve outside the

building. To prevent the steam, when blown off, from disintegrating the mortar in an opposite wall, some boards were set up to receive the force of the discharge, and as often as the superheated steam was blown against them, the boards were set on fire! This occurred in an oil refinery in Pittsburg, Pennyslvania.

"Some years since, while on a visit at the Institution for the Deaf and Dumb, in Illinois, of which an esteemed friend is principal, we called attention to the manner in which some steam coils were secured to wooden supports, and pronounced them unsafe. They were shown to be a thousand feet or so—as the pipes ran—from the boiler, and our caution only provoked a smile. The next year we visited at usual, and, upon taking the principal's hand, he said—before exchanging salutations or inquiries—'Come with me, I wish to show you something,' and led the way to the room where, a year ago, his attention had been called to the steam pipe. 'There,' said he, 'examine that; I have been saving it for you since last winter; the coil fell down, and investigation showed that the screws had let go because the wood had been turned to charcoal and had no more strength to hold them.' The experience was new to him, it may be old to some of our readers, but its introduction here will illustrate a fact which is now becoming an admitted one among those who have given this matter attention.

"An experiment illustrating the effects of superheated steam was tried as follows: Steam was taken from an ordinary boiler through a pipe forty feet long. Ten feet from the farther end a collar of wood was fitted closely to the pipe; ten feet near the boiler a lighted kerosene lamp was placed under the pipe. In ten minutes the wooden collar was on fire."

LIGHTING.

Numerous fires have been caused by lamps in mills. These should be constructed of metal, and not glass, as the glass readily breaks. High test oils only, with a flash test of 150 degrees or over should be used.

The watchman should burn lard oil in his lamp, which is safer than mineral oil. In order that he may not, by trimming his lamp in the mill cause fires, as has been the case, his lamp should be inclosed and provided with a lock and key, the key being fastened in some fireproof room in the building, so that when the lamp burns poorly, the

watchman will have to return to the fire-proof room and trim and fix his lamp there, and not in the mill among the loose stock and material.

In order to increase the safety of lamps, so-called safety lamps have been invented. These are glass lamps inclosed in metal cases, which protects the glass recepticle from breaking. Westland's lamp has, experimentally, proved successful, although I have no further evidence of how it has worked in practice. This consists of a globe of glass, containing the oil, surrounded by a concentric sphere, containing water charged with carbonic acid gas under pressure. As soon, therefore, as the lamp is broken, carbonic acid gas is set free and the flames extinguished.

Gas is the general material yet used for illumination. Gas lights should be inclosed so as to keep stock from falling into the flames, and from igniting fine particles of dust and flies in card and picker rooms. Especial care must be taken to clean the tops of inclosed gas lights well before lighting up, as many fires have been caused from dirty inclosed lanterns In order to safely light up gas lights several devices have been constructed, among which are Mr. Whiting's electric torch, in which the gas is lit by means of an electric spark. Another is a German device by Bodmer, by means of which an inclosed torch is pressed down over the gas jet and the gas in escaping is lighted.

[Several of these devises were then shown with slides projected on the screen.]

Gasoline vapor, or as frequently called, gasoline gas, is sometimes used. Where gasoline machines are used, the machines, especially the carboretting arrangement, must be placed at least fifty feet from all other buildings. The gas machine building should be on a piece of ground lower than the other buildings, so that the gasoline vapor which may escape, and which is heavier than air, may flow away from the buildings. Care must be taken to have all supply pipes descend towards the machine building, so that any vapor which may have condensed in its passage from the carboretter of the mill may flow back into the carboretter. Care must be taken to have a drip-cock attached to every jet, so that the pipes may be well emptied of gasoline before lighting the vapor. Gasoline vapor is extremely explosive and dangerous.

Of late a new excellent gaslight has been introduced, the so-called Siemens' Regenerative Burners. Care must be taken where these are erected, to have the ventilating flues, which carry off the products of

combustion, well constructed of metal, free from wood work, as these lamps give off a great amount of heat, and readily ignite wood work which is in contact with the ventilating flue.

The electric light is daily coming more into use, and when properly installed is very safe. Daily tests should be made for grounds. Great care should be taken to have all wires properly insulated, all connections in wires well made, the proper amount of cut-outs, switches and safety catches; and, where arc lights are used, take proper care of the glowing carbon points, which, in falling, have caused fires. One of the greatest hazards is caused by improper insulation, as moisture will cause an electric current to pass from one wire to another, especially through water which contains salts, such as lime, which it dissolves in passing through ceilings or walls.

[Numerous illustrations of electric lights were shown, showing their hazards and how they can be safely installed.]

FRICTIONAL ELECTRICITY.

Electricity is frequently caused by the friction of belts on pulleys, a fact known in Germany for a long time, but first described in our country, I believe, by Mr. F. W. Whiting. This has been the cause of fires and should be guarded against by connecting all parts on which the electricity accumulates with the ground by means of wires attached to the object and a gas, or preferably, a water pipe. This is one of the most prolific sources of fires in the heavy coating rooms of oil cloth factories, as the electric sparks readily ignite the benzine vapors present. In one of our largest Philadelphia works of this kind, the iron receiving racks were so charged with electricity that long sparks could be drawn from them, but since they have been properly "wired," not a trace of electricity is left in them.

MEANS FOR EXTINGUISHING FIRE.*

INTRODUCTION.

Before we can enter into a discussion and description of how to fight the phenomena of combustion we must understand a few preliminary facts. If we rapidly draw our hand through the surrounding space, we feel a certain amount of resistance. This resistance is due to a gaseous body which surrounds us on all sides, and which we term air, a substance known to the ancients, who tried to weigh it. As for example, Aristotle filled a bladder and weighed it, then exhausted the air and reweighed the bladder, and actually believed he had thereby determined the weight of the atmosphere. It was not, however, until the advent of the experimental era under Galileo and Torricelli that its weight or pressure was determined. It was found at the level of the sea, to be about fifteen pounds to the square inch.

This surrounding fluid consists of two gases, oxygen and nitrogen; not, however, chemically combined, but merely mixed in the proportion—in round numbers—of seventy-nine parts of nitrogen and twenty-one of oxygen. Nitrogen, which is fourteen times heavier (atomic weight) than hydrogen, is a gas entirely negative in its qualities; it does not support combustion, and its purpose in the air is merely to act as a diluting agent so as to make the effects of oxygen less violent. Oxygen, the great supporter of life and also the great destroyer in nature, is an odorless, colorless gas, sixteen times (15·95 atomic weight) as heavy as hydrogen. It and its combinations constitute the greater part of our earth. The crystalline rocks which consist of silicates combined with oxygen, contain from forty-four to forty-eight per cent. of oxygen. Water, which is a compound of oxygen and hydrogen, contains one part of oxygen to two parts of hydrogen. It is this element which causes all these phenomena which we ordinarily term combustion. Phenomena which it causes while ordinarily diluted with nitrogen (air) are greatly intensified when the element is pure; and even metals, such as iron and steel, when ignited in a globe filled with oxygen, burn with brilliant scintillations.

We are now ready for the question, "What is combustion?" I

* A lecture delivered before the Franklin Institute, January 9, 1885.

would define it as a chemical union of oxygen with some other element or elements, accompanied by an evolution of light and heat, while similar unions of other substances, not with oxygen directly, I will term "chemical combination." Substances which unite with oxygen are termed combustible substances, while oxygen is a supporter of combustion. These terms, although but relatively correct,—as combustion might be defined as an act of a chemical union accompanied by an evolution of light and heat—are for our purposes very convenient and will be retained throughout.

We must, before entering into the subject under discussion, understand what is meant by the temperature of ignition or the ignition point. It has been found that before a substance can ignite (take fire) in either the air or oxygen, a certain temperature must be reached, and this necessary temperature is termed the ignition point or temperature of ignition. While for some substances this point is very low, for others it is extremely high, as, for example, nitrogen will only unite with oxygen at the intense heat of the electric spark; while phosphorus burns slowly at 10°C. (50°F.), as may be noticed in the dark (phosphorescence), it does not burn brightly until heated to 60°C. (140°F.), and zinc ethyl and phosphuretted hydrogen ignite in the air at the ordinary temperature.

But most bodies do not unite with the oxygen of the air rapidly enough at ordinary temperatures to produce light and heat, but must be heated for a production of active cumbustion. In the case of the decay of organic matter or the rusting of metals oxidation goes on slowly, producing heat, and the total amount of heat that a decaying log produces in the long time required for its destruction is exactly equal to the amount of heat produced by its rapid oxidation (burning) in a stove. We, therefore, distinguish between quick and slow combustion.

The temperatures of different flames vary greatly. Bunsen found that the temperature of the flame of hydrogen burning in air is 2,024°C., temperature of a hydrogen flame burning in oxygen 2,844°C., carbonic oxide 1,997° when burning in air, and 3,003°C. when burning in oxygen.

In order to measure the quantity or strength of a material or force, we must have a measure or standard of comparison. The standard for the measurement of heat, if the expression be allowed, as heat is a force and not a material, is the "thermal unit.," the amount of heat required to raise the temperature of one cubic gramme of water one

degree Centigrade. This measure is now almost universally employed by scientists, although the old English caloric unit, the amount of heat required to raise one pound of water one degree Fahrenheit, is yet sometimes employed. Two other units are also used; in Germany, the amount of heat required to raise one kilogramme of water one degree Centigrade is much used; while the unit of one pound of water to one degree Centigrade is sometimes employed.

COMBUSTION IN OXYGEN.

One gramme of	Thermal units.	Observer.
Charcoal	7,273	Lavoisier.
"	7,167	Dulong.
"	7,912	Depretz.
"	7,714	Grassi.
"	8,080	Favre and Silbermann.
"	7,900	Andrews.
Diamond	7,770	Favre and Silbermann.
Natural graphite	7,811	" "
Gas carbon	8,047	" "
Hydrogen	34,462	" "
"	33,808	Andrews.
"	34,180	Thomsen.
Sulphur	2,220	Favre and Silbermann.
"	2,307	Andrews.
Phosphorus	5,747	"
Zinc	1,301	"
Iron	1,576	"
Tin	1,233	"
Copper	602	"
Marsh gas	13,063	Favre and Silbermann.
"	13,108	Andrews.
"	13,120	Thomsen.
Olefiant gas	11,858	Favre and Silbermann.
"	11,942	Andrews.
"	11,957	Thomsen.
Carbon monoxide	2,431	Andrews.
"	2,403	Favre and Silbermann.
"	2,385	Thomsen.

Numerous experiments, made by different scientists, have proved beyond a doubt that a constant quantity of heat is given off when the same weight of the same substance burns to form the same products of combustion, whether the combustion proceeds slowly or rapidly. Numerous measurements of the amount of heat disengaged by the combination of different substances with oxygen have been made, of which those of Andrews, Favre, Julius Thomsen and Silbermann are the most correct. The above table compiled by Roscoe, shows the heat of combustion in thermal units for one gramme of substance burnt.

WATER.

Water was the first material employed to extinguish fire. One of the best materials and means for extinguishing fire are well-filled galvanized iron water-buckets. These should have conical bottoms, so that they can not be used for other purposes than those for which they are intended. They should be kept filled at all times. A very good method of keeping them filled is to appoint a special man for this purpose, and fine him one dollar for every bucket which is found empty. It should be the particular duty of the watchman to examine the buckets daily and report on their condition; and, in order to increase his surveillance, the money obtained for fines skould be presented to the watchman, whose vigilance in this respect will thereby be greatly increased. Reliable automatic devices are always preferable to means depending on human agency, and for this purpose the "automatic electric low water alarm" is highly recommended; this is a device which sets an electric bell in the superintendent's office into operation as soon as one quarter of the contents of a bucket evaporates, and continues to ring until the bucket is filled. Buckets should be of iron, not wood, as wooden buckets, when they are dry or partially empty, shrink and become leaky. They should be well covered, first, with a zinc solution, which is generally called galvanizing, and then with good tar or asphaltum paint, put on hot, which will cause buckets to last much longer than they otherwise would. The word "Fire" should be painted on them with large letters—red is to be preferred as that color can be seen best—so that one may know their purpose and readily discover them in case of emergency. All factories should have trained bucket brigades, as it is not easy to use a bucket properly. It seems an easy matter to pour water upon a burning substance; but when we consider that, in the majority of cases, it is impossible to reach the point of fire, and

that, therefore, water must be thrown from a distance, it is self-evident that it is quite an art to throw the contents of a bucket on the spot necessary, without spilling or wasting the greater part of it. In order to make a bucket brigade efficient, they should practice once or twice a week. Every room which contains buckets should contain large casks with wide opened tops, so that the buckets may be readily refilled. I frequently find casks with the top so small that it is almost impossible to intrude the bucket into the opening and procure water, and it would be utterly impossible, in case of fire, when people are frightened to a craze. It is a notable fact that more than twice as many fires are exsinguished by buckets than by any other means. The importance of having factory buildings properly equipped with them is therefore self evident.

PUMPS.

The oldest and first-described fire pump is that described in the Spiritalia of Hero, 150 years B. C.

[A slide showing this pump was projected on the screen.]

One of the best and strongest pumps, in places where water power is used, is the French Rotary. Its chief merit lies in its great strength. Its operation is due to the displacement of water between the teeth of two coarse gears. Its construction is very simple. There are no weak and small parts which break; no valves which require constant attention, while it is very durable and works out slowly. It should take its supply from the flume, and should be about 18 inches above the water level, so that it may not be flooded. Driving belts should not be used, as a fire will soon destroy these. In the same way bevel gears are objectionable, because they are apt to slide, causing the various parts to stick, and the pump to become worthless when most needed. Friction gears, when the pump is strongly erected, are perhaps best; although, when the heat becomes great, they become warped, but stand longer than any other arrangement.

[A number of slides, showing the construction and the general arrangement of water-power pumps, were then shown.]

STEAM FIRE PUMPS.

The pre-requisite conditions in choosing steam fire pumps are, that they should be simple, strong, and, which is included in the foregoing, there should be as few small and weak parts as possible, as these are

apt to get out of order and break. All fire pumps should be supplied with a relief valve (which relieves excessive pressure), as when the pump is running at full head, hose is frequently bursted, and as it is often impossible to reach the pump during the fire, the hose with which it is connected becomes worthless when most needed, as was the case at the fire of a large chemical works a short time ago. A fire pump should be placed where it is least exposed to fires; preferably outside in a fire-proof compartment, so that the attendant may have access to the pump to the very last, and the pump may still work even if the entire remainder of the property be destroyed.

[A number of slides, showing the general construction of the various fire pumps, were projected on the screen.]

VERTICAL PIPES.

I do not think much of the outside vertical, or, as they are sometimes called, Palmieri pipes; which are run along the outside of buildings, extending to the roof; the intention being that, in case of fire, the Fire Department will attach the engine to the lower end and the hose to the connection on the roof. It has, however, by experience, been demonstrated that, with few exceptions, as in the case of a few very high buildings, firemen prefer to carry their hose on their ladders to the top of the building, and are, therefore, of little value in case of fire, as firemen will not use them.

Inside stand-pipes or vertical pipes, on the contrary, are of great importance. These should be connected with tanks of large capacity or with good force pumps, so that strong pressures may be obtained in them at all times, as the pressures of the City Water Departments, especially on higher stories, are inadequate. We frequently, in our Philadelphia Specials, find vertical pipes connected with the City water supply, which, on being tested, will throw a stream of not more than ten or fifteen feet. Care should be taken to place all vertical pipes away from exposed positions. These pipes should never be placed along walls exposed to the wind, as, in winter, the cold will cause the water to freeze and burst the pipes, the arrangement becoming worthless. They should always be placed in positions which will be least apt to be destroyed by fire, and which, in case of fire, will be least exposed to flames and smoke. Fire-proof stairway houses are well adapted for this purpose, as firemen in them are able to fight the fire until the last moment, as they know they still have a fire-proof way of retreat, and can, at any moment, protect themselves by

closing the fire doors which lead into the stairway house. Vertical pipes should be of ample size, so that the requisite amount of water can be drawn from them. A good pressure in it is the pre-requisite of an efficient stand-pipe.

[A number of slides were shown, explaining the various modes of erecting stand-pipes.]

HYDRANTS.

In the ordinary hydrant, the water is at all times contained in it.

[This was shown and explained by a number of stereopticon views.]

In order to keep the water from forcing into the upper portion of the hydrant, which is apt to deteriorate it, causing parts to corrode, several devices have been constructed, such as the Matthews', and the Chapman hydrants, in which the water is turned on by valves in the lower end of the hydrants, which is, therefore, eliminated from the upper parts of the plugs. A similar construction is used for our ordinary fire plugs. The name, "fire plug," is derived from an English expression, and in its original appellation is entirely correct. An English plug is a device for reaching water, in the following manner: The main water supply, running along the street, is punched with holes at various parts, and these are closed by wooden plugs, tightly driven in. On top of these a box is fitted, which is filled with manure or straw, in order to keep the water from freezing. In case of fire, the fire department must first remove the manure or straw, knock out the wooden plug, and make connection with the opening, and pump the water from the pipe. Plugs of this kind are still used, to a certain extent!

It was through the admirable labors of the father of a member of this Institute, Mr. Frederick Graeff, that plugs were first invented and introduced in our city and throughout the United States, and their introduction has now become general in every civilized country in the world.

[A number of slides, illustrating the various hydrants, was shown.]

VALVES.

Only straight valves should be used for turning on water. Mr. Woodbury states he found, in a number of experiments made by him at Holyoke some time ago, that a two-inch globe valve reduced the pressure from 80 to 40 pounds per square inch.

[This was further explained by means of slides projected on the screen.]

A valve or hydrant which is not water-tight, on being closed by hand, without great effort, is to be deprecated, and should never be employed, as it is liable to break, on account of the excessive strains applied to certain parts when it is opened and closed. Jenkins' and Chapman's straightway valves can be recommended.

[These were shown and explained by means of slides.]

It is absolutely necessary that all valves in a factory should open in one direction only. I have frequently found that even the same factory contained valves which opened in different directions. It is no wonder, therefore, that mistakes are made, especially when people are highly excited as in case of fire. In order to overcome this difficulty, valves should be labelled with an arrow and the word "*open*" painted on it conspicuously, so that any person, even unacquainted with the valve, may be enabled to open it properly. It is an unfortunate coincidence that even among mechanics and engineers, the words right-hand and left hand valves do not signify the same. In some parts of the country the word "right-hand" signifies the motion of the hands of a clock, while in other districts, as used even by some persons in the same district, the term signifies the opposite. It would be well if conventions would take the matter in hand and settle the term once for all.

Chapman's gate, which was introduced some time ago, is a very good one, as it can be opened or shut by one turn of the hand to every inch diameter of the gate. For example, a six-inch gate is shut or opened by six turns of the hand wheel, etc. As further advantages for the gate are claimed, "that it opens in the natural manner, advancing stem, full opening, with the utmost quickness of motion, without water hammer."

[Several gates and methods of construction were then projected on the screen.]

HOSE.

I prefer unlined linen hose for inside use even to more expensive kinds. Woodbury states that twelve samples from different manufacturers, weighing from three and three quarters to four ounces per foot, burst when new, at pressures of from 420 to 650 pounds per square inch. Several experiments made by myself, with similar hose,

gave even better results, bursting at pressures, between 415 and 670 pounds per square inch ; but it is but fair to state that the best samples were furnished me for the express purpose of testing, and may, therefore, have been especially strong.

In order that a hose may remain in good condition, it must be kept dry, and should not be wound on reels. A hose, on a reel, after some time, on being unreeled, assumes a winding form similar to an Archimedean screw, and when run off in a hurry, is apt to *kink*, and cut off the supply of water at times when it is most needed. Hose should be kept on a pin, and should be laid on with looping ends, as loose twine is frequently kept on a nail..

[The manner was then shown by a sketch on the board.]

The pin should be protected with a round, broad saddle or back, so that the hose may not crack, as it will when hanging on too sharp an edge. If hung properly on a pin, it may be drawn off without the slighest danger of *kinking*.

It is absolutely necessary that uniform couplings should be introduced throughout, not only for regular fire departments, but also for factories. The old screw coupling labors under the serious disadvantage that if the hose is not permanently attached to the hydrant, in the event of fire and excitement, it is difficult to attach the hose properly. For this purpose Jones' patent coupling, which is now used in most of our public fire departments is excellent, as the hose may be quickly attached, even by excited persons. Care must, however, even in this simple coupling, be taken to press the joints together tightly, as complaints are often made by incompetent persons, that the joints leak. If they are put together properly, no leakage will occur. In the ordinary Jones' coupling the rubber strip, which forms the tight joint, extends a short distance into the coupling, and therefore, to a certain extent, retards the flow of the water and reduces the pressure, it has been claimed by some as much as 20 per cent. Clay's coupling, in which the rubber strip does not protrude into the opening, or water way, is an important improvement, as it does not retard the velocity or pressure of the stream. A great advantage with the Jones' coupling is that with an increase of pressure, up to about 300 pounds to the square inch, the joints become tighter, and are, therefore, less liable to leak.

NOZZLES.

I still prefer the old leather nozzle, with a metal tip, to the long metal nozzles, which are now much used. A leather nozzle may be bent in all directions which one of metal cannot be, and as in fighting fire it is very frequently necessary that the fireman may stand behind a projection, and direct the stream by bending the nozzle without exposing much of his body to the heat and flames, the importance of short metal nozzles or leather nozzles are evident. Morse's monitor nozzle is an important invention, as by simply turning a crank the nozzle may be turned in any position and held there. The so-called "spray" nozzle is a new and valuable invention, as it is frequently impossible for firemen to see on entering a burning building, on account of smoke, sometimes created by insignificant fires, which it is impossible to detect for some time, on account of the smoke generated. The spray nozzle produces a fine spray, which precipitates the smoke around it, giving the firemen an opportunity to see and follow up the fire.

Drip couplings are good for places in which the hose is attached to hydrants at all times. They consist of couplings with small openings or slots in the bottom, so that any contained water or water created by the leakage of valves, will not reach the hose which would deteriorate it, but will escape through the slot before reaching the same.

Pressure at Hydrant. Pounds per sq. inch.	Discharge per minute. Gallons.	Distance reached by jet.	
		Horizontal feet.	Vertical feet.
15	84	54	26
20	98	62	35
25	112	72	45
30	122	80	52
35	132	88	60
40	140	96	67
45	149	103	75
50	157	111	80
55	165	118	88
60	172	125	93
65	180	132	101
70	186	139	106
75	193	145	111
80	199	150	116
85	205	156	121

The above table, taken from the excellent work of Mr. Geo. A. Ellis, serves as a basis for estimating the diameter of distributing mains, for the passage of water through them, and is found for 100 feet of rubber hose and one inch smooth nozzle:

[A number of lantern projections illustrated the various nozzles.]

TANKS.

Tanks should be of large size, even larger than is usually thought to be sufficient. They should be provided with an overflow valve, and the contents should not be allowed to freeze. This can be prevented by passing an exhaust steam pipe through the tank, or by mixing the water with salt, which will at the same time prevent the formation of organic slimes, which are objectionable. The tank should be in a position least exposed to the cold north winds. An alarm valve should be introduced in the tank, which gives an alarm, either by whistle or bell, whenever the water falls below a certain height in the tank. A better arrangement is an automatic electric alarm, which can be put in connection with the office of the superintendent, and gives the alarm there whenever the water falls below a certain height in the tank, being at the same time a tell-tale on the engineer in charge of the pump. Tanks should always be placed on the strongest part of a building, and on that part which will be apt to stand longest in case of fire. A fire-proof stair-way house, well sheltered from the flames of the surrounding buildings, is an excellent position.

SPRINKLERS.

For some years past mills have been provided with perforated sprinkler pipes, which extend through the mill lengthwise, and are perforated with numerous holes, one-tenth of an inch in diameter and from eight to ten inches apart. When a fire occurs, the water is turned on by a valve outside of the building, water rushing into the pipes, and being discharged through the openings. The great objection which is found to this system in practice is that the water is not confined to those spots only at which the fire occurs, but is distributed over the entire premises provided with such sprinkler pipes, and frequently it was found that the damage done by the water was inestimably greater than that which would have been done by the fire.

Another great objection to it is that it requires human help in order

to turn it on, and all who have had experience in *fire technology* know of how little value that is in case of fire.

To overcome these various objections, automatic sprinklers were invented a long time since, the first being turned on by means of levers with weights attached to them, which were held in position by strings, which on burning through released the lever and set the sprinklers in operation. At present, automatic sprinklers consist of a system of pipes, which extend near the ceiling, and the water is released, by valves attached to the pipes, by the heat created by the fire. The valves are kept closed by means of fusible solder, which melts at a temperature of 150°F. or over. The heat which arises from the fire melts the solder joint of the valves immediately over the place where the fire occurs, the water is expelled and is put in just that place where it it is needed at the time, and not thrown over the entire premises, as was the case with the former sprinklers.

Automatic sprinklers are divided into two great classes, (1) *sealed sprinklers*, such as the Rose, Bishop, Burritt, Parmelee, etc.; and (2) the *sensitive*, such as the Neracher, Kane Bros., Brown & Hall, Buell, Burritt, Grinnell, etc.

Automatic sprinklers have now been in use for about twelve years, and a series of tests made by Mr. Woodbury shows that the fusible solder has not deteriorated in that time, and still possesses all its valuable properties. It was formerly thought that the solder would in the course of time, through corrosion (oxidation and pressure), become worthless, which these tests seem to disprove. The effectiveness of automatic sprinklers is shown by the fact that out of 110 fires in factories in which they were introduced, and of which the amount of damage was accurately determined, for 67 or 60·9 per cent. no damage was claimed; for 12 or 10·9 per cent. the damage done was less than $250; for 8 or 7·2 per cent. the amount of loss was between $250 and $500; for 11 or 9·9 per cent. between $500 or $1,000; for 12 or 10·9 per cent. between $1,000 or $20,000.

I consider automatic sprinklers of a specially great value in those parts of factories in which finely divided organic substances or dusts are created, as, for instance, in the picker and card rooms of textile mills, in flour mills, malt mills and so on, as the water projected from the ceilings precipitates the dust, and therefore removes one of the most dangerous sources and causes of fire, and prevents the fire from extending further by means of the ignitible dust.

[The various sprinklers which have been tried and found effective were then shown and explained by means of slides projected on the screen.]

By a series of tests made by Professor Morton, President of the Stevens' Institute, for the New York Board of Underwriters, it was shown that the tank which supplies the sprinklers should in every case be at least ten feet above all pipes; and the following table shows the amount of water which is used in fifteen minutes for pipes of the following diameters, to which the following number of sprinklers are attached:

Tank, ten feet above all pipes.

Diameter of Pipe.	Number of Sprinklers Supplied.	Gallons running for fifteen minutes.
¾ inch	2	212
1 "	4	424
1¼ "	5	530
1½ "	9	954
2 "	16	1,696
2½ "	25	2,550
3 "	36	3,816
3½ "	49	5,194
4 "	64	6,784
5 "	100	10,600
6 "	144	15,264

STEAM JETS.

Live steam is one of the best substances we possess for extinguishing fires in small inclosed compartments. All small rooms, such as picker and drying rooms, should be supplied with ample sized steam jets. In order to make steam jets effective they should be turned on from the outside, the valves being located in some secure position, as the first impulse of every one, in case of fire, is to run out; when reason returns, a person is more apt to turn on a valve from the outside than he would be to enter the burning room and turn the valve. But, in order to make a steam jet absolutely effective, it should be automatic. For this purpose I invented the following device: On the steam supply pipe a ring is tightly fitted, to which is attached a rod, which, on its

end, is formed into a fork-like projection. On top of this fork a bar is placed, to which a rope, impregnated with substances which will cause it to burn rapidly when ignited, is attached; and the two sections of the rope are held together by means of a fusible solder joint. This rope serves to hold in place a lever to which a weight is attached. This lever is in connection with a valve. I use for this purpose a spring valve, constructed by the Bellfield Valve Company, which will not corrode, and which works easily and well in all cases. To the small rod, which rests on the open fork, a rod is attached, which passes through a small slot or pipe in the wall to the outside, and to it a convenient handle is attached. Now, let us suppose that a fire occurs in a picker room, and that, as is generally the case, the employés run out. Should one of them be cool headed enough, he would go to the outside, pull the handle, and thereby draw the bar, which rests loosely on the open fork, from the fork; the lever would drop and open the steam into the room. But, let us suppose that the employé has not the proper amount of coolness, and he runs away without turning on the steam from the outside. Then the temperature will rise to 160°F., the temperature at which the fusible solder joint will melt and separate (the solder joint may be fixed for any temperature by altering the composition and proportions of the ingredients of the solder); the lever will be released, as in the former case, and the steam turned on. Let us, however, suppose that through some unforseen accident the solder joint would not work, then we still have as a third means the extremely inflammable rope, which would soon be ignited, and burn through, thus causing the valve to be turned on. We therefore have three resorts, one of which would undoubtedly work.

In all steam jets, be they automatic or otherwise, valves should be used which can be turned on readily. I have frequently found valves so tightly corroded and stuck fast that they were worthless in case of fire.

EXTINGUISHERS.

Extinguishers contain water which is of value on account of the carbonic acid gas which it contains, which replaces the air, the burning body being at the same time incrustated in a layer of salts.

Carbonic acid is an excellent extinguishing means in any form. I suppose you all have seen the experiment of extinguishing a number of candles placed in a trough, by means of pouring carbonic acid gas in one end and allowing it to flow through.

One of our large soda water establishments has extinguished several small fires in their building and neighborhood by means of the carbonic acid contained in their soda water apparatuses. A druggist extinguished a small lot of benzine, which had taken fire in his store, by a bucketful of soda water, which he sensibly drew from his fountain and poured upon it, instead of using ordinary water, which would have been of no avail.

Extinguishers, in the proper sense of the term, as first used, consist of apparatuses containing gas, which in case of fire is released, supplying the place of the air and thereby extinguishing the fire. The apparatus of Cartier consists of a cylinder of sheet-iron which is tested for a pressure of eighteen atmospheres. To both ends are attached bottoms of sheet steel, and by means of a specially constructed filling pipe in the upper end water and bi-carbonate of soda are poured and the pipe tightly closed, and when used tartaric acid is injected by a special device, which causes the formation of carbonic acid gas and sodium salts. These are partially absorbed by the water, and the gas produces a pressure of from four to seven atmospheres on the contained water, which, when the cock of the nozzle is opened, produces a strong stream. Shaeffer and Budenberg use the same substances under a pressure of ten atmospheres.

Instead of the expensive tartaric acid, Zabel and Dick first substituted sulphuric acid. In Dick's apparatus the sulphuric acid is contained in a separate glass, which, in case of fire, is broken and then reacts on the bi-carbonate of soda. In Zabel's apparatus the sulphuric acid is contained in a glass cylinder, which is turned upside down in case of fire, and the cover, thereby opening, mixes with the salts and produces the gas.

Similar to these are the apparatuses of Masnata, who releases carbonic acid gas with sulphuric acid and the carbonates of different elements; and the apparatuses of Baragwanath and Van Wisker.

Among our efficient American extinguishers may be mentioned the Harkness Pneumatic Extinguisher. A new extinguisher called "The Climax," which is before you; in this sodium bi-carbonate and oxalic acid is used. The extinguisher is charged with water, and the dry material is placed in two receptacles above it. When used, the dry material is dropped into the water by relieving the bottoms of the receptacles which are attached by hinges; carbonic acid gas is generated and oxalate of sodium formed, the charged water being ejected by

means of a small pump attached to the apparatus. This is an excellent extinguisher, while used on the floor, as it may be frequently refilled, fresh substances being added, and the pumping continued; but it cannot be used on ladders, as is necessary in reaching ignited substances on high walls or ceilings.

Platt's extinguisher, which has been kindly loaned me for this evening, has been used with great success for many years. Its great value consists in its simplicity, as the most ignorant workmen can be readily taught to use it. It is put into operation by merely turning the valve handle as far to the left as possible, and turning the extinguisher upside down. This firm also manufactures small extinguishers, which can readily be carried on the back, and which can be used on ladders for reaching substances which cannot be reached by a stream from the ground. These extinguishers were employed in the Electrical Exhibition.

In choosing an extinguisher we must, as in choosing all other machinery, take those which are simplest and least apt to get out of order, and those which contain substances, and arrangements by which the metal of the apparatus is not corroded, (as many are put into the market which will last but a few years, on account of the corrosive nature and method of placing the ingredients.)

Of late, so-called hand grenades have been used. These, which are highly ornamental, I do not advise. The extinguishing material is contained in bottles, which must be broken in order to cause the extinguishing liquid to be spread over the flames. It is exceedingly difficult to break the bottles over a fire, by taking two bottles, as is generally advised, and breaking them over the point of danger; while we frequently find the bottles, which are strongly made, are not broken by throwing them into places which cannot be got at such as burning yarn, raw stock, waste, and so on. The joke of a prominent underwriter when he first saw them is not perhaps out of place, who said that in case of fire persons would be apt to look for a corkscrew to remove the cork in the bottle before putting out the fire. The wire racks in which some grenades are placed are valuable additions. These consist of wire baskets so arranged that when the grenades are removed from them, a fire alarm is given.

EXTINGUISHING POWDERS.

Bucher's extinguishing powder partially rarefies the air, by heating the atmosphere, and also withdraws air in enclosed spaces, producing sulphurous acid, which tends to smother the fire. According to Heeren, the value and extinguishing results of burning sulphur of carbon does not consist in the absorption of oxygen from the air, and the effects of burning Bucher's powder are not produced by the resulting gases replacing the air, but he believes that the gases which are thus caused, consisting largely of sulphurous and carbonic acid gas, having a higher specific gravity than air prevent all draught or circulation around burning substances, and that, therefore, air cannot reach them and supply the oxygen necessary for combustion. Liquified sulphurous acid is one of the best means for extinguishing fire.

Bucher's powder, as prepared by Wittstein, contains 60 parts of saltpetre, 36 parts of sulphur and 4 parts of charcoal. Schweizer prepares the powder with the following composition: Saltpetre, 58·53 parts; sulphur, 36·33 parts; charcoal, 3·14 parts; sand, 75 parts, and oxide of iron, 1·25 parts. Heeren prepares Bucher's powder in the following manner: Saltpetre, 63·73 parts; sulphur, 28·93 parts; charcoal, 3·80 parts, and oxide of iron, 3·54 parts.

The ingredients are not powdered quite as finely as for the manufacture of gunpowder. They are then mixed and placed in small packages of paste board, so tightly packed that only a very sharp instrument can separate the particles. The composition can readily be ignited and burns (without exploding) with a strong white flame and strong penetrating odor and smoke. Out of every pound, 4·82 cubic feet of gas are produced, consisting of 2·36 cubic feet of sulphurous acid, 1·10 cubic feet of carbonic acid, and 1·36 cubic feet of nitrogen. According to Bucher, about one pound of the material should be used for every 240 cubic feet of space. In case of fire, the powder is thrown into the fire, whereby the results above described will be produced.

These powders are only of value in small enclosed rooms, without many ventilating openings, and has practically proved valueless in places exposed to great draughts. One great objection to it is that it is extremely dangerous to life, as several cases of severe accidents have occurred in Europe. It has been of great value in drying rooms, where substances coated or impregnated with petroleum compounds are dried; as, for instance, Dorn reports a case in which a severe fire in the drying room of an oil cloth factory was extinguished by it.

The extinguishing composition of Zeisler consists of 60 parts saltpetre, 36 parts sulphur, and 4 parts charcoal and lime. The mass, after being mixed, is compressed into cartridges by means of a hydraulic press, and several of them are connected by a hermetically enclosed easily ignitable fuse.

Gruneberg's composition consists of 20 parts potassium chloride, 50 parts potassium saltpetre, 50 parts sulphur, 10 parts rosin and 1 part magnesium di-oxide, tightly packed in the form of cartridges.

Johnstone's powder consists of equal parts of potassium chloride, rosin, potassium saltpetre and black oxide of manganese, moistened with water-glass, and then pressed into briquettes, a number of which are shipped in one box, being connected by a fuse which can readily be ignited and thus ignite the mass. The box being suspended near the ceiling.

OTHER MEANS.

Other means for extinguishing fire which have been used are sulphide of carbon, liquified sulphurous acid, the gaseous products from under the boiler, water-glass, salt, magnesium chloride, sulphate of allumina, ammonia gas, borax, sodium phosphate, Glauber salts, soda, etc.

Burning fats, rosins, pitch, etc., can be successfully extinguished by placing wire gauze of very fine mesh over the burning mass. The reason for this is, as is the reason for the efficiency of the Davy safety lamp, that flames are not transmitted through wire gauze, as the wire being a good conductor, conducts away the heat, preventing the flames from passing.

Sand is a very good mode of extinguishing fires originating in pitch, tar, petroleum and its products; as in this case water will be of little value, while sand, when piled on to burning substances, cuts off the supply of oxygen from the air, causing the flames to be extinguished.

FIRE BRIGADES.

Fire brigades were in use among the ancients. Thus we find under Augustus Cæser, A. U. C. 732, that the Romans had a fire brigade of 600 freedmen.

Organized fire brigades in factories, should be drilled at least once a week. Every man should have his special duty assigned him and know exactly what to do in case of fire; only these men should be

allowed to take part in extinguishing fires; strict rules should be promulgated, that every one not belonging to the fire brigade must remove from the premises as soon as the fire alarm is given, thus giving the firemen room to work. The brigade should be drilled at a different hour weekly, for if they be always drilled at the same time, they will be prepared for the event; will go through their drill at this time in good manner, but when a fire starts at another time they will be excited and slow to get to work. For this reason it is necessary that the chief of the brigade give the fire signal at different times every week, and thus get the department on duty at times when they do not expect it. He will thereby, accustom his people to get to work rapidly at all times, and as they do not, at the time when the alarm is first struck, know if it is merely an alarm or an actual fire, in the course of time get over the excitement which is generally incidental to such an occurrence. It is absolutely necessary, that the chief insists that on all occasions his men get to work immediately. If he allows slovenly practice, he will have the same affairs in case of fire.

WATCHMEN.

A good watchman is of great advantage in a mill, but in order to effectively control him, watch-clocks or time detectors, as they are more frequently called, should be introduced, as a watchman, without a watch-clock, in the majority of cases, is worthless. It is a standing joke at the Patrol that the first thing they have to do in arriving at a fire is to save the watchman, as he is almost invariably sound asleep and would burn to death.

[Various time detectors were shown on the screen, such as the stationary clock, to which a button lever is attached, which must be pushed at required times, either hourly or half hourly, as the rounds may be, and will the next morning, from the perforations on a time card, show the superintendent if the watch has been properly carried on. The Buerk's time detector which consists of a clock, which the watchman carries with him, while the keys are fastened. The marks on the card next morning show whether the watchman has made his rounds.]

Special care must be taken to have the keys or stations provided in all dangerous places where fires are likely to originate, so as to keep them under constant supervision.

A clock gains in value by simplicity, and the manner in which it is protected against tampering of watchmen as it is frequently to their

interest to conceal breaches of discipline by tampering with the clocks.

For this reason an electric time detector is an excellent arrangement it consists of buttons placed at the various stations, the watchman, in pressing these, gives a signal impression on a time card in a clock in the superintendent's office. It is very difficult for the watchman to tamper with the apparatus as his only means is to cut the wire, which in well managed establishments would cause his immediate dismissal.

[Various electric watch-clocks were then thrown on the screen and explained.]

FIRE ALARMS.

The first fire alarms used were either large bells, gongs, or whistles which, by their peculiar sound, would make known that a fire had originated. The ordinary steam whistle is an excellent arrangement. This consists of a hollow hemisphere against which the steam is blown from a valve, the metal is set in vibration, imparts this motion to the contained and surrounding atmosphere, setting this also in vibration, thus producing a sound. Where steam whistles are used as fire alarms it is necessary that these should be very loud and have a shrill peculiar sound, different from all others in the neighborhood, so that persons may at once recognize it.

Automatic fire alarms have been introduced for some time. One of the oldest is that of Joseph Smith, first introduced in 1802, which was set in operation by means of a cord, which being burnt through released a lever in connection with a steam whistle or a bell.

Another apparatus used was a wire extending over a mercury receptacle, connected with a lever, which it held in place. When the temperature rose, the mercury contained in the receptacle touched the wire, amalgamated the same, which caused the tensile strain on the wire to part it, relieve the lever and cause an alarm. These devices were never of much practical value.

Of late the so-called thermostats have been introduced. These are of various construction; some consisting of strips of different metals, tightly fastened together, which, by their unequal expansion, bend, thereby forming contact with a metal strip, which closes an electric circuit, causing an alarm to be struck at the fire station.

Another consists of a bulb containing mercury, into the bottom of which a wire is melted, and in the upper end a wire which does not touch the mercury, is hermetically sealed. When the temperature

increases, the mercury in the column rises and touches the upper wire, forming contact, closes the circuit, and gives the alarm at the station.

Another very ingenious device is that of Fein of Stuttgart, which consists of an arrangement held in place by means of a spring, the spring in its turn being held in place by a fusible cylinder. The temperature rises, destroys the fusible cylinder, the spring is released, and contact is made, an electric circuit formed giving the alarm.

[A number of these devices were then thrown on the screen and explained.]

OUR BRANDS OF

FIRE HOSE.

"Unique" Brand. Is our popular brand, which has gained such a splendid record in so many large cities.

"Keystone" Brand. Is also a double or jacket hose like the Unique, but made of lighter material and designed for cities of from ten to fifty thousand inhabitants.

"Patrol" Brand. Is a solid fabric hose.

"Safety" Brand. The Safety or Mill hose is designed for factories, store houses and hydrant purposes.

"Lawn or Garden Hose." Is made with a $\frac{1}{2}$ or $\frac{3}{4}$ inch internal diameter. It is warranted to stand 500 pounds to the square inch, is not injured by exposure to sun or weather and can be left out all summer with perfect safety.

LIBERAL DISCOUNT TO THE TRADE.

WHAT WE CLAIM FOR OUR HOSE.

The Fabric Fire Hose Company's claims for superiority in fire hose consist of the **Balanced Woven** principle for which they hold patents, whereby the circular or weft threads run in opposite directions, thus equalizing the strain on the hose when under pressure; this applies particularly to the "Unique" and "Keystone" brands.

During the past six years the Company has triumphantly demonstrated by successful experiments and the severest practical tests, that their patented process by which the yarn is treated before weaving renders the hose absolutely **Mildew and Rot-Proof** under any reasonable use or abuse.

Being "twill-weave" it presents a smooth water way and a **Superior Wearing Surface**—everyone knows that twilled goods will outwear plain woven goods.

Hundreds of chief engineers have over their own signatures unhesitatingly pronounced the "Warwick" hose the most perfect fire hose ever invented, possessing as it does a **Smooth Bore or Water-Way,** thereby doing away with nearly all friction, a desideratum alone sufficient to recommend it to all practical firemen.

Again, its extreme **Light Weight and Pliability** render it capable of being handled with great ease and rapidity, a consideration of the utmost importance when every moment is valuable.

Finally, this hose combines **lightness** with great **strength** and **durability.** Being softer and more pliable, fewer men are required to handle it and a larger quantity can be carried upon a reel.

For further information, address:

Fabric Fire Hose Company,
1 Barclay St., New York City.

PRICE LIST.

CLASS A. Includes the various brands of Fire Department hose, upon which we shall at all times endeavor to meet the ruling market prices, for the best grade of hose. Cheap hose, which is necessarily made of poorer materials, is the dearest that can be bought. Write for samples and prices.

CLASS B. Safety, Mill or Hydrant Hose. 1 inch (internal diameter), 28 cents per foot. 1½ inch (internal diameter), 45 cents per foot. 2 inch (internal diameter), 50 cents per foot. 2½ inch (internal diameter), 55 cents per foot. Couplings extra. Larger sizes to order.

MISCELLANEOUS. Fabric, leather, rubber or brass discharge pipes, pipe mountings, couplings, spanners and a full line of Fire Department supplies, constantly on hand. For samples, prices or other information, address our agents or

Fabric Fire Hose Company,
1 Barclay Street, New York.

The Buell Sprinkler is adapted to be used with electrical connections to make operative an electric circuit when any one of a series of sprinklers is open, and to thereby sound an alarm, turn on a water supply and start a power pump to give a second water supply to the sprinkler system, or perform either of said operations.

When these sprinklers are used without the electrical connections, the opening of any one of a series of sprinklers will produce an instant alarm, and turn on an auxiliary water supply, by mechanism actuated by the lowering of water pressure in the pipes of the sprinkler system.

In either of the systems for giving an alarm it is contemplated to furnish the means for sounding such alarm upon the premises protected, and simultaneously at a remote place, as the house of a superintendent, or a central station.

The Buell thermostatic circuit is a constantly charged electric circuit, which is formed of lengths of wire held in electrical continuity by a solder that melts at 155° Fahrenheit, thus automatically opening the circuit, and giving an instant and definite alarm. The Buell thermostatic circuit is adapted to be used separate from the sprinkler system, affording the simplest and most efficient Fire Alarm ever invented.

This Fire Alarm is designed to be used in isolated mills, and is arranged to give an alarm on the premises protected, and also at the superintendent's house, or other convenient place; or to be used in cities to give a definite alarm for each building upon apparatus at a central station that is open day and night, and is provided with both telegraph and telephone communication with the headquarters of the city fire department, so that an automatic alarm of fire is instantly communicated to the city fire department from the central station of this company, announcing the building and floor of the building where a fire has occurred.

The street circuits of this system are so constructed and arranged as to transmit a fire alarm even when broken or grounded, affording greater certainty than any system yet devised. This system depends entirely upon normally closed electric circuits, which are ruptured by heat, and are known to be in order at all times, as otherwise an alarm will be sounded to give notice of any derangements of the circuits, whether due to accident, neglect, or malicious interference.

The circuits and apparatus of the Buell system are so constructed as to transmit a fire alarm signal that is different in character from an accidental or false alarm, thus avoiding the calling out of fire departments except in cases of actual danger. The Thermostatic devices used are wholly different from any that have been known before. They require no adjustment, cannot get out of adjustment, are not damaged by age, will not be made inoperative by corrosion, and are so cheap as to admit of the most profuse distribution.

For information apply to

J. T. MAXWELL,

229 Chestnut St., Philadelphia.